



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of)	MAIL STOP AF
Lachezar Komitov et al.)	
Application No.: 10/562,050)	Group Art Unit: 1794
Filed: December 23, 2005)	Examiner: Sow Fun Hon
For: A LIQUID CRYSTAL DEVICE AND)	Confirmation No.: 4262
A METHOD FOR)	
MANUFACTURING THEREOF)	

DECLARATION UNDER 37 C.F.R. § 1.131

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

We, Lachezar KOMITOV, Bertil HELGEE, and Johan FELIX, declare as follows:

1. We are each over the age of 21 and are competent to make this declaration.
2. Each of us is a named inventor of U.S. Patent Application Serial No. 10/562,050 ("the present application").
3. We are familiar with U.S. Patent No. 6,985,200 (Miyachi et al.), cited in the Examiner's final Office action dated July 2, 2008.
4. In order to show that the invention of claims 1-4 and 6-19 of the present application was reduced to practice prior to the earliest U.S. filing date of Miyachi et al., we have attached Exhibits 1 to 3.
5. Exhibit 1 is an extract from laboratory notebooks that record experiments conducted by one of us or at our direction that resulted in the synthesis and characterization of two different side-chain polymers (polymer BHL 461 has the same chemical formula as polymer BHL 444). Polymer BHL 444

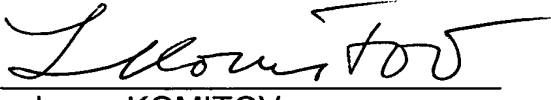
corresponds to the polymer of formula VI in the present application. Polymer BHL 464 corresponds to the polymer of formula XVI of the present application. The experiments recorded in these laboratory notebooks were carried out and recorded prior to October 7, 2003.


6. Exhibit 2 is a series of reports of experiments conducted by one of us or at our direction that record the assembly of liquid crystal cells using the polymers produced according to Exhibit 1. Reports designated 310-3 record the assembly of liquid crystal cells using polymer BHL 444. Reports designated 315-4 records the assembly of liquid crystal cells using polymer BHL 464. The experiments recorded in these records were carried out and recorded prior to October 7, 2003.
7. Exhibit 3 is an extract from laboratory notebooks that record the results of experiments of the cells produced according to Exhibit 2, and filled with n-4'-methoxybenzylidene-n-butyraniline (MBBA) and MLC6608 (a liquid crystal material available from Merck) or nematic mixture E7 (a liquid crystal material available from Merck). Cells produced using BHL 444 were filled with MBBA/MCL6608. BHL 444 is a surface director alignment material having positive dielectric anisotropy. MBBA/MCL6608 is a liquid crystal material having negative dielectric anisotropy. Cells produced using BHL 464 were filled with E7. BHL 464 is a surface director alignment material having negative dielectric anisotropy. E7 is a liquid crystal material having positive dielectric anisotropy. Exhibit 3 reports the testing and evaluation of the filled cells as functional liquid crystal materials, and verifies that the cells function as expected, and that the orientation of the molecules used therein is directly


controllable by an electric field. These experiments were conducted and recorded prior to October 7, 2003.

8. In addition, we have also attached Exhibit 4, which is a draft application prepared prior to October 7, 2003 by Swedish patent counsel and provided to the inventors for comment, on September 10, 2003. The draft contains claims and supporting written description that is substantially the same as the claims and description of the present application.
9. Subsequent to receipt of the draft application from Swedish patent counsel, the inventors reviewed the draft and met with Swedish patent counsel on October 16, 2003 to discuss the draft. These discussions resulted in the decision to add further embodiments to the disclosure.
10. A revised application draft was prepared by Swedish patent counsel and sent to the inventors for review on October 28, 2003.
11. Subsequent to receipt of the revised draft, the inventors reviewed it and discussed the revised draft with Swedish patent counsel by telephone conference on November 4, 2003. As a result of this discussion, additional adjustments and additions were made to the text of the draft. This revised draft was sent to the inventors for review on November 10, 2003.
12. The inventors accepted the revised draft and communicated this to Swedish patent counsel on November 14, 2003, who filed the application as Swedish priority application no. 030304-8 on November 18, 2003.
13. All statements made herein based upon our own knowledge are true, and all statements made herein on information and belief are believed to be true; further, these statements were made with the knowledge that willful false

statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the present application or any patent issued thereon.

Date: November 3, 2008 By: 
Lachezar KOMITOV

Date: Nov. 3, 2008 By: 
Bertil HELGEE

Date: October 30, 2008 By: 
Johan FELIX

U.S. Serial No. 10/562,050
Declaration under 37 C.F.R. 1.131

EXHIBIT 1

STANDARD 1H OBSERVE

Pulse Sequence: s2pul

Solvent: DMSO

Ambient temperature

UNITY-300 "polymr1"

PULSE SEQUENCE

Relax. delay 10.000 sec

Pulse 90.0 degrees

Acq. time 3.000 sec

Width 8000.0 Hz

24 repetitions

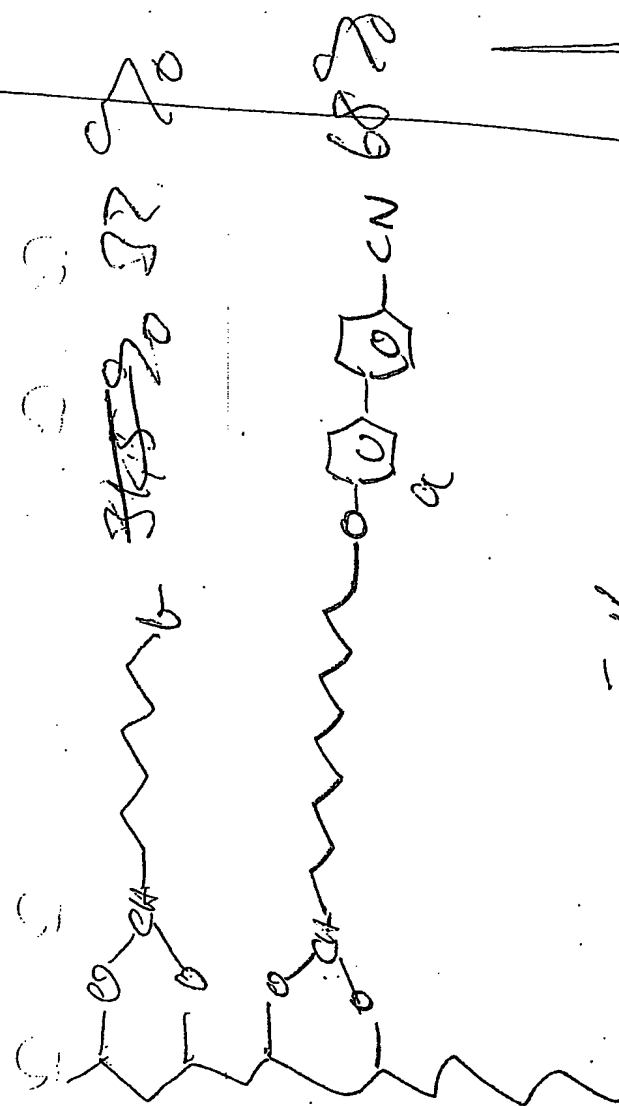
OBSERVE H1, 299.9924498 MHz

DATA PROCESSING

Line broadening 0.3 Hz

FT size 65536

Total time 5 min, 12 sec



Standard 1H
 1H NMR spectrum

Chemical shift (ppm)

0.88

1.58

2.18

5.14

ppm

2.04

73.23

4.31 = 0.8385

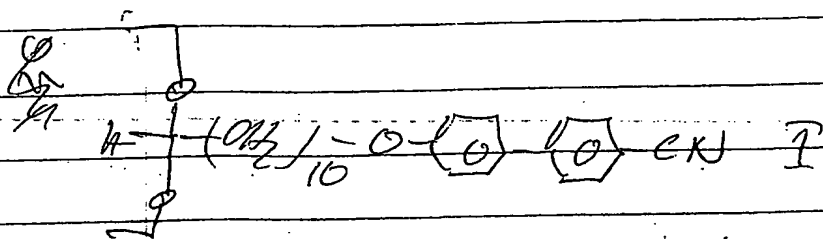
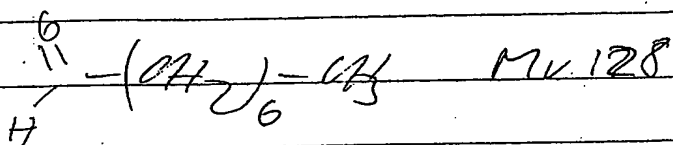
2.95

3.33

2H/1H

2H/1H

RAC 461


 $C_{28}H_{58}NO_2$ MW 432


MW 128

1.8g I 4.1 mmol
 128mg Oktanol 1 mmol
 50 ml Torr TAF

9.5 mmol Polyethylalkohol 418 mg
 0.2g TSOH

anfällig 23gr

alkyle 1.2g

BNC NMR

CN/R = 2/1 PSS 444

STANDARD 1H OBSERVE

Pulse Sequence: s2pul

Solvent: CDCl3

Ambient temperature

UNITY-300 "polmr1"

PULSE SEQUENCE

Relax. delay 10.000 sec

Pulse 90.0 degrees

Acq. time 3.000 sec

Width 8000.0 Hz

24 repetitions

OBSERVE H1, 299.9924522 MHz

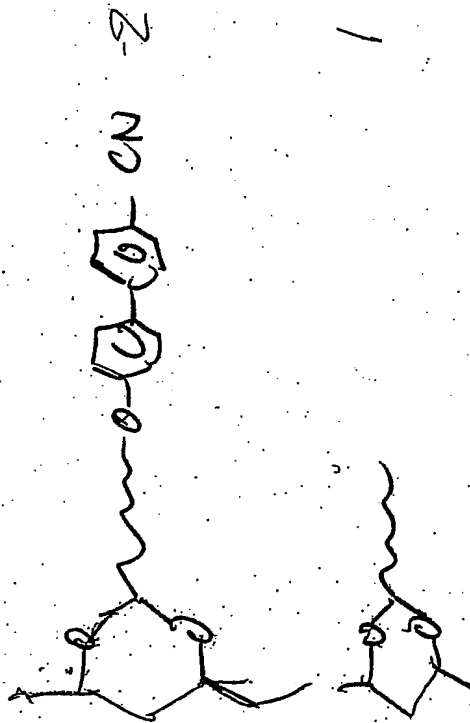
DATA PROCESSING

Line broadening 0.3 Hz

FT size 55536

Total time 5 min, 12 sec

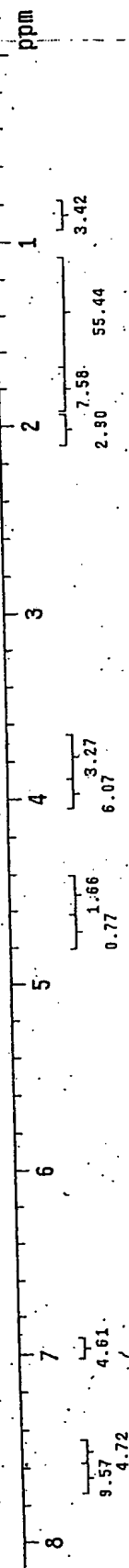
PVA



8. PVA 4.11

2.30/4

1.14/11



191

VX 1 101

bh1461

Pulse Sequence: s2pul1

Solvent: CDCl3

Temp. 20.0 C / 295.1 K

UNITY-300 "pol1amr1"

PULSE SEQUENCE

Relax. delay 1.000 sec

Pulse 90.0 degrees

Acq. time 3.760 sec

Width 8000.0 Hz

64 repetitions

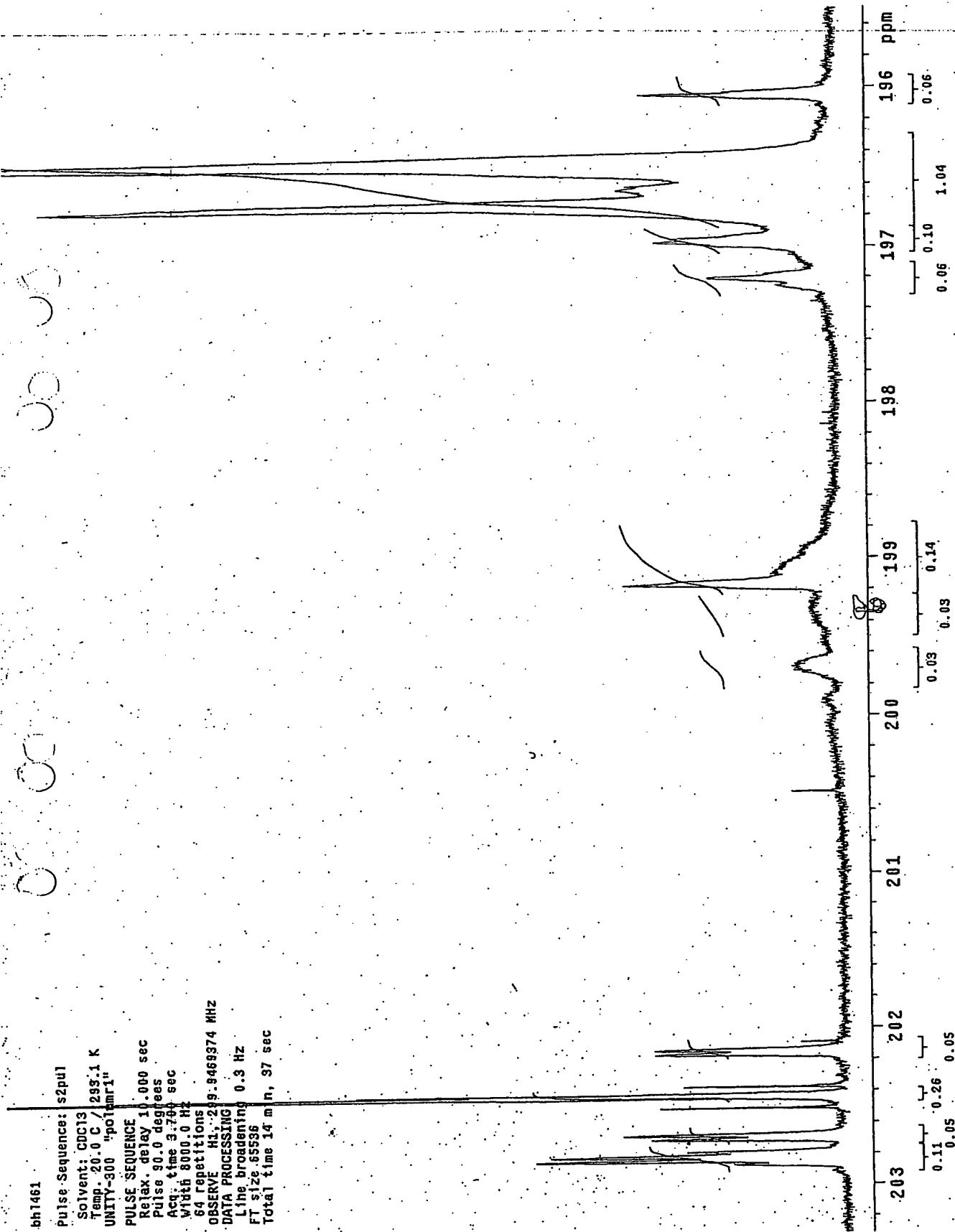
OBSERVE H1: 283.9469374 MHz

DATA PROCESSING

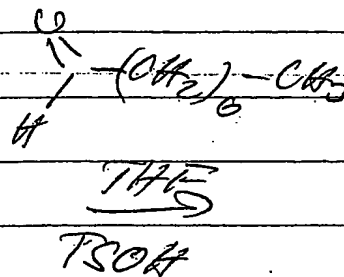
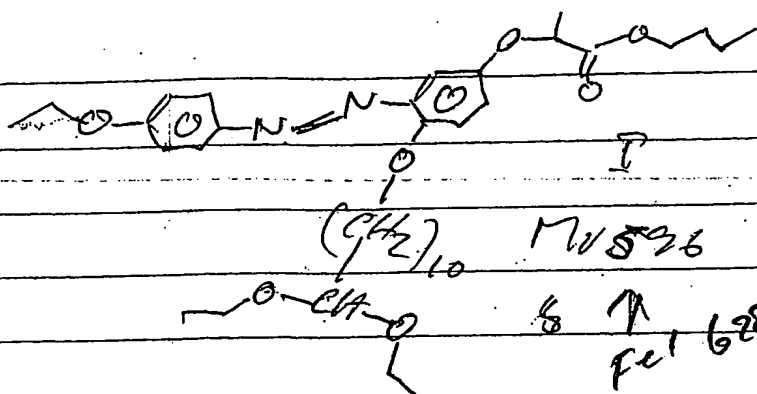
Line broadening 0.3 Hz

FT size 65536

Total time 14 min, 37 sec



B# 464



1.5 g I 2.57 mmol
 Chloranil 2.5 mmol MW 128
~~4.5 mmol~~
 9 mmol (OH) PVA = 376 mg

50 ml form THF
 0.2 g TSOH · 1 H₂O
 reflux

Orsfall 3 ggr $CHCl_3$ / MeOH

Produkten är helt ren
 men det som skall vara där
 finns där.

Gör ett par celler för att testa
 det.

utbytte 0.30 g

Putso Sequence: s2pu1

Solvent: CDCl₃

Ambient temperature

UNITY-300 "polymer 1"

PULSE SEQUENCE

Relax. delay 10.00 sec

Pulse 90:0 degrees

Acq. time 3.000 sec

Width 800.0 Hz

24 Variations

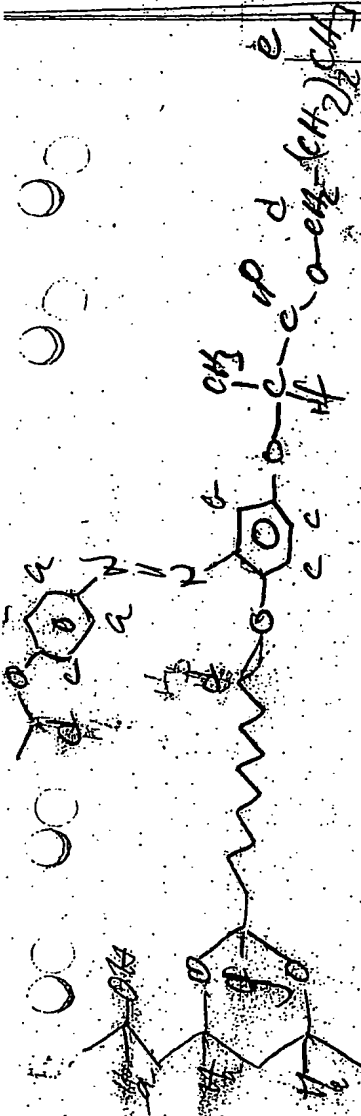
299.9924522 MHz

DATA PROCESSING

0.3 Hz

ET-8128 65586

Total time: 5 min. 12.5 sec



E! held you

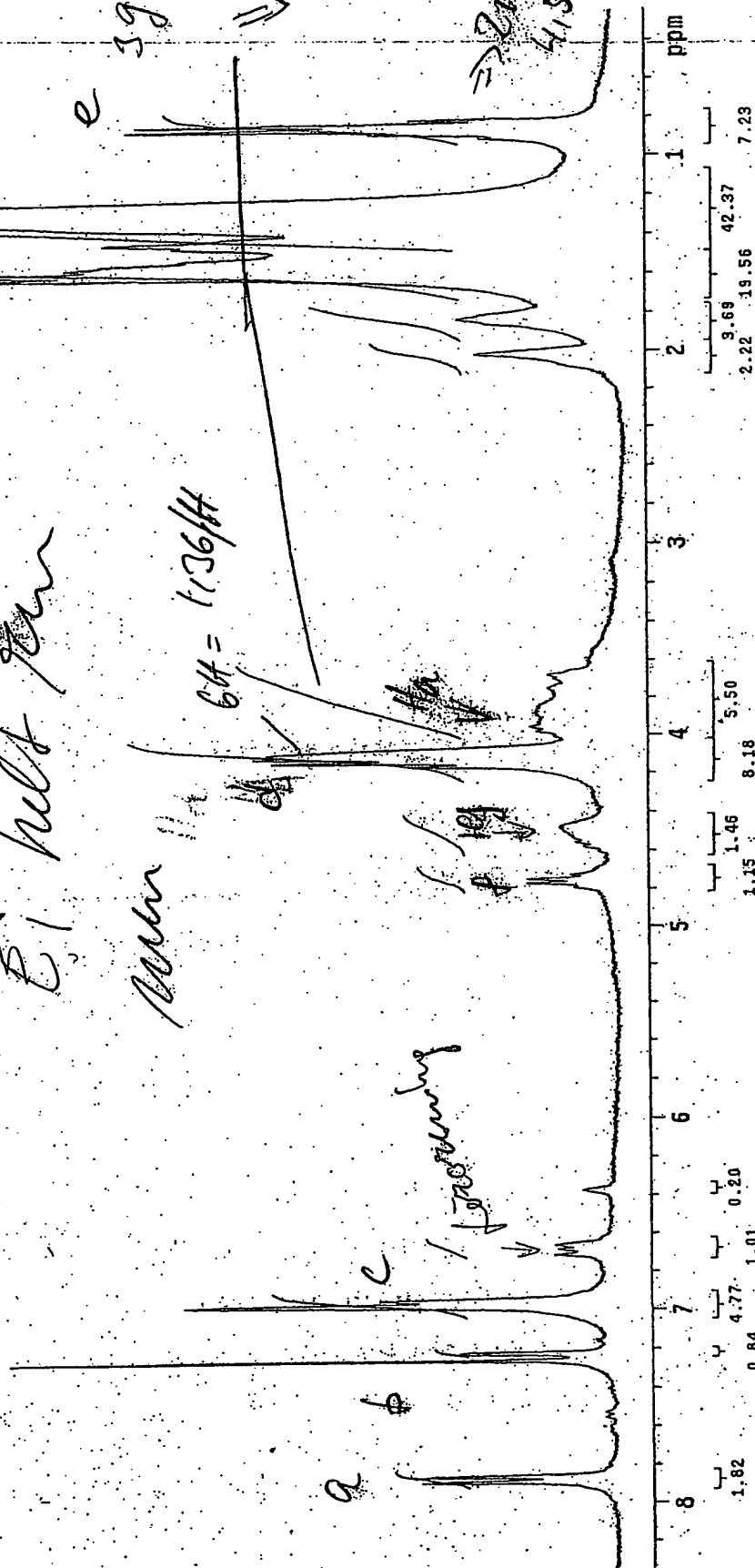
Caplan

6.4 = 1.36/4

39 = 4138

2104/02/02

⇒ ZIF A20
4.15 octanol



U.S. Serial No. 10/562,050
Declaration under 37 C.F.R. 1.131

EXHIBIT 2

310 – 3 A/B

KEYWORDS:

BHL 444 ("PVX"). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

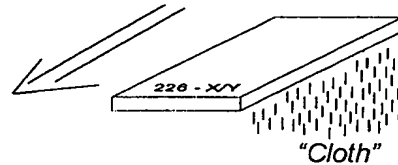
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

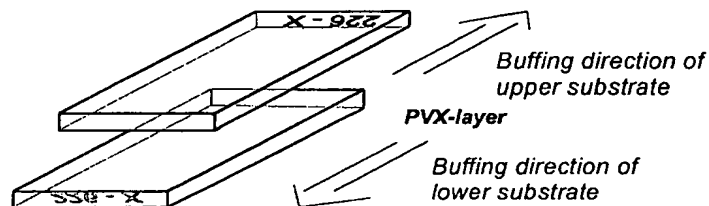
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5µm spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

310 – 3 C/D

KEYWORDS:

BHL 444 ("PVX"). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

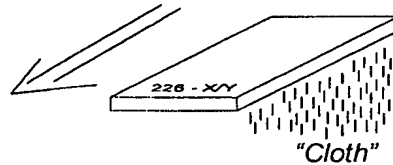
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

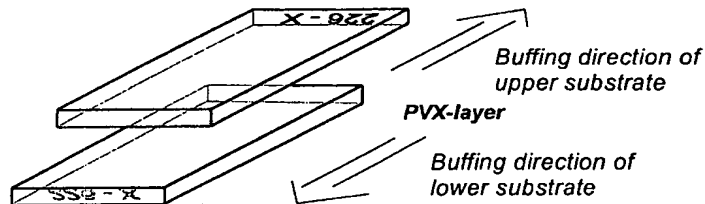
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5 μ m spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

310 – 3 E/F

KEYWORDS:

BHL 444 ("PVX"). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

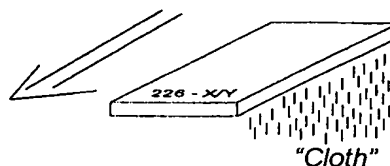
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

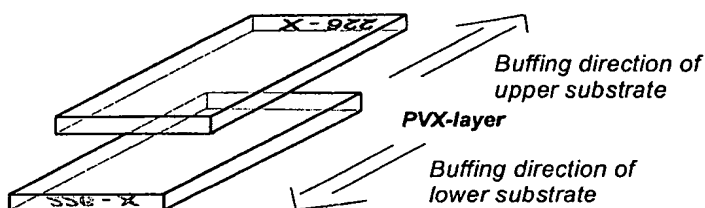
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5 μ m spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

310 – 3 G/H

KEYWORDS:

BHL 444 ("PVX"). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

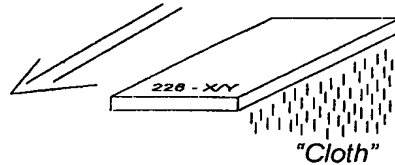
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

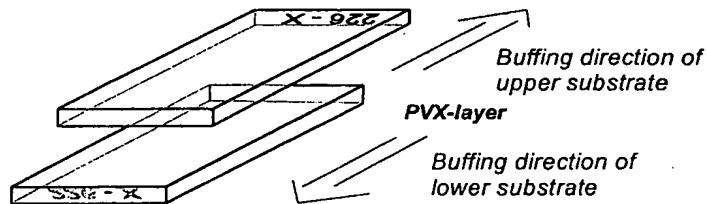
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5 μ m spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

310 – 3 I/J

KEYWORDS:

BHL 444 ("PVX"). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

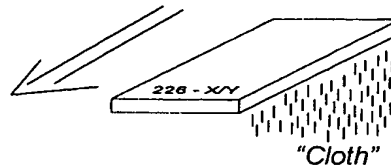
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

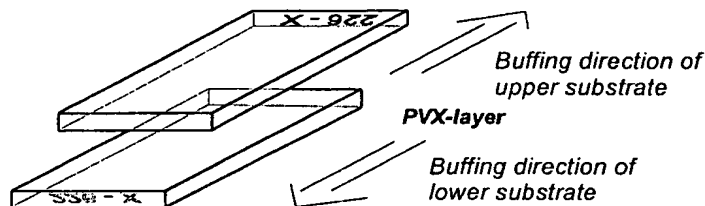
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5µm spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

310 – 3 K/L

KEYWORDS:

BHL 444 ("PVX"). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

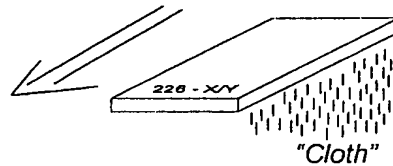
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

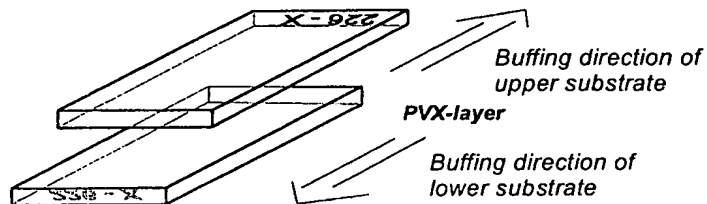
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5 μ m spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

310 – 3 M/N

KEYWORDS:

BHL 444 (“PVX”). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

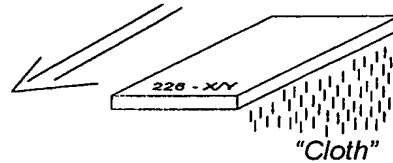
Before application of mixture, the substrates were rotated for a few seconds. This for “throwing off” particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

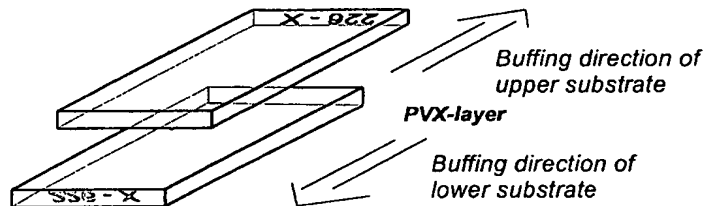
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5 μ m spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

310 – 3 O/P

KEYWORDS:

BHL 444 (“PVX”). >0,7%, dissolved in THF, filtered mixture.
2,5µm cell gap.
Buffed.

GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

CLEANING: Cleaned with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform. Blowed by N₂.

COATING MIXTURE: BHL 444, less than 0,74%, dissolved in THF (mixed 16/2). Due to some particles, or undissolved BHL 444 (?), the mixture was filtered (0,2µm filter). Hence the concentration is probably lower than 0,74%.

COATING:

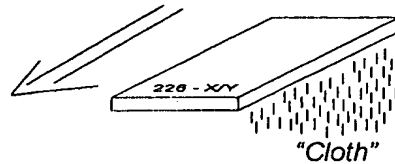
Before application of mixture, the substrates were rotated for a few seconds. This for “throwing off” particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

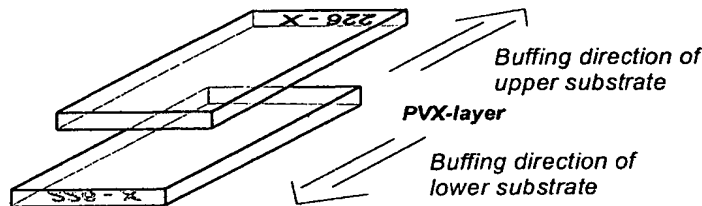
ALIGNMENT:

PRETREATMENT: Substrates heated to +125°C for approx 10-15 minutes, then set to cool.

BUFFING: When cool, the substrates were rapidly brushed by a cloth. This was done 5 times with little pressure (2 of 5, on a scale of 5). Direction:



CELL ASSEMBLY: 2,5 μ m spacer (plastic) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 14 minutes. Direction of the substrates in the cell:



ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Unknown type of cord (from Johan), cut from reel.

FINAL CLEANING: . The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

315 – 4 A/B

KEYWORDS:

BHL 464 (“PVX”) 0,47%, dissolved in THF, filtered mixture.
4µm spacer.

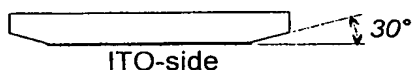
GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

Edges grinded by diamond grinding paper.
Cross section of substrate, grinding angle



CLEANING: After grinding the substrates were kept in water. Then several washings of the substrates by distilled water. Dried clean with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform.

COATING MIXTURE: BHL 464, less than 0,47%, dissolved in THF. Stirred (by Spinbar), dissolved, for about half an hour. Then the mixture was filtered (0,2µm filter).

COATING:

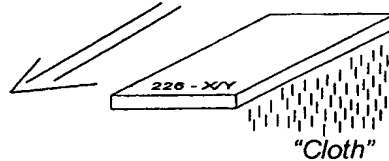
Before application of mixture, the substrates were rotated for a few seconds. This for “throwing off” particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

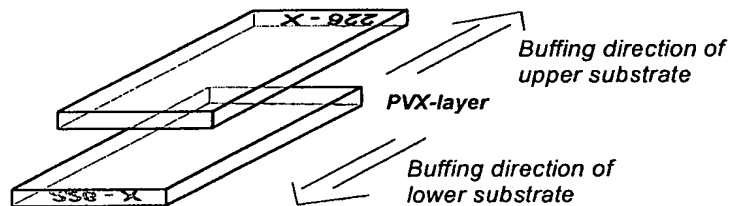
ALIGNMENT:

PRETREATMENT: Substrates heated to +120°C for 15 minutes in oven, then taken out to cool.

BUFFING: The substrate was buffed 5 times, with a pressure of 2 on a scale of 5. Buffing direction of substrate:



CELL ASSEMBLY: 4µm spacer (glass fibre) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 7 minutes. Direction of the substrates in the cell:



SEALING OF CELL SIDES: The sides, the joint of the substrates, strengthened by applying NOA68 glue. Exposed under UV-light for 14 minutes.

FINAL CLEANING: The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Cord with 105mm length (ELFA 55-241-52).

315 – 4 C/D

KEYWORDS:

BHL 464 ("PVX") 0,47%, dissolved in THF, filtered mixture.
4µm spacer.

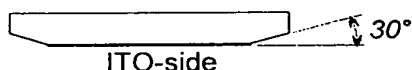
GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

Edges grinded by diamond grinding paper.
Cross section of substrate, grinding angle



CLEANING: After grinding the substrates were kept in water. Then several washings of the substrates by distilled water. Dried clean with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform.

COATING MIXTURE: BHL 464, less than 0,47%, dissolved in THF. Stirred (by Spinbar), dissolved, for about half an hour. Then the mixture was filtered (0,2µm filter).

COATING:

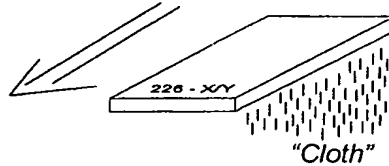
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

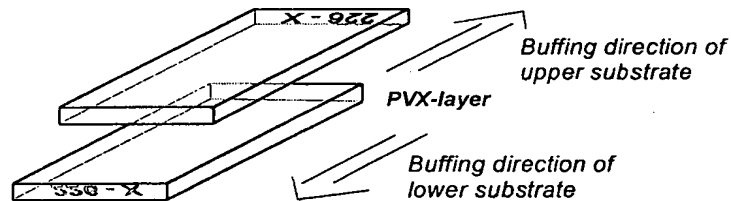
ALIGNMENT:

PRETREATMENT: Substrates heated to +120°C for 15 minutes in oven, then taken out to cool.

BUFFING: The substrate was buffed 5 times, with a pressure of 2 on a scale of 5. Buffing direction of substrate:



CELL ASSEMBLY: 4µm spacer (glass fibre) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 7 minutes. Direction of the substrates in the cell:



SEALING OF CELL SIDES: The sides, the joint of the substrates, strengthened by applying NOA68 glue. Exposed under UV-light for 14 minutes.

FINAL CLEANING: The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Cord with 105mm length (ELFA 55-241-52).

315 – 4 E/F

KEYWORDS:

BHL 464 ("PVX") 0,47%, dissolved in THF, filtered mixture.
4µm spacer.

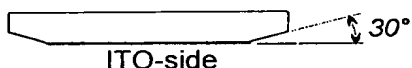
GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

Edges grinded by diamond grinding paper.
Cross section of substrate, grinding angle



CLEANING: After grinding the substrates were kept in water. Then several washings of the substrates by distilled water. Dried clean with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform.

COATING MIXTURE: BHL 464, less than 0,47%, dissolved in THF. Stirred (by Spinbar), dissolved, for about half an hour. Then the mixture was filtered (0,2µm filter).

COATING:

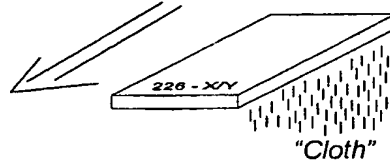
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

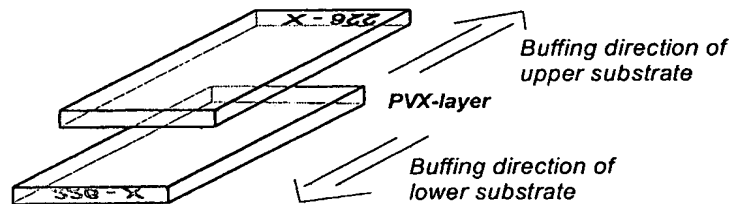
ALIGNMENT:

PRETREATMENT: Substrates heated to +120°C for 15 minutes in oven, then taken out to cool.

BUFFING: The substrate was buffed 5 times, with a pressure of 2 on a scale of 5. Buffing direction of substrate:



CELL ASSEMBLY: 4µm spacer (glass fibre) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 7 minutes. Direction of the substrates in the cell:



SEALING OF CELL SIDES: The sides, the joint of the substrates, strengthened by applying NOA68 glue. Exposed under UV-light for 14 minutes.

FINAL CLEANING: The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Cord with 105mm length (ELFA 55-241-52).

315 – 4 G/H

KEYWORDS:

BHL 464 ("PVX") 0,47%, dissolved in THF, filtered mixture.
4 μ m spacer.

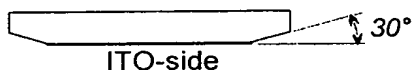
GLASS:

1,10mm, 80 Ω/\square . MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5 \times 12,5mm.

Edges grinded by diamond grinding paper.
Cross section of substrate, grinding angle



CLEANING: After grinding the substrates were kept in water. Then several washings of the substrates by distilled water. Dried clean with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform.

COATING MIXTURE: BHL 464, less than 0,47%, dissolved in THF. Stirred (by Spinbar), dissolved, for about half an hour. Then the mixture was filtered (0,2 μ m filter).

COATING:

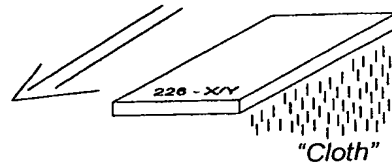
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

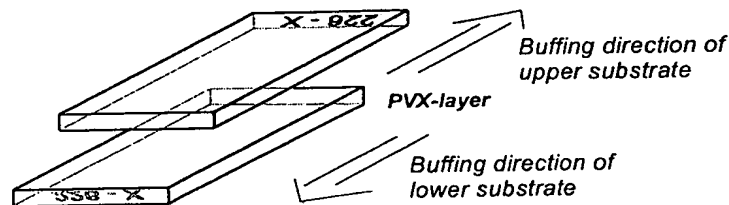
ALIGNMENT:

PRETREATMENT: Substrates heated to +120°C for 15 minutes in oven, then taken out to cool.

BUFFING: The substrate was buffed 5 times, with a pressure of 2 on a scale of 5. Buffing direction of substrate:



CELL ASSEMBLY: 4µm spacer (glass fibre) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 7 minutes. Direction of the substrates in the cell:



SEALING OF CELL SIDES: The sides, the joint of the substrates, strengthened by applying NOA68 glue. Exposed under UV-light for 14 minutes.

FINAL CLEANING: The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead";
Heat: 3, Sonic Power: 3. Cord with 105mm length (ELFA 55-241-52).

315 – 4 I/J

KEYWORDS:

BHL 464 ("PVX") 0,47%, dissolved in THF, filtered mixture.
4µm spacer.
Substrates heated –again- after buffing.

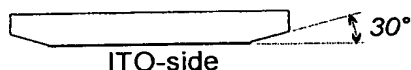
GLASS:

1,10mm, 80 Ω/□. MBC, batch No. 0R1429, 2000-02-24.

SUBSTRATES:

Cut to 9,5×12,5mm.

Edges grinded by diamond grinding paper.
Cross section of substrate, grinding angle



CLEANING: After grinding the substrates were kept in water. Then several washings of the substrates by distilled water. Dried clean with cleanroom tissue and Isopropanol. Then the substrates were kept in chloroform, and washed in an other bath of chloroform.

COATING MIXTURE: BHL 464, less than 0,47%, dissolved in THF. Stirred (by Spinbar), dissolved, for about half an hour. Then the mixture was filtered (0,2µm filter).

COATING:

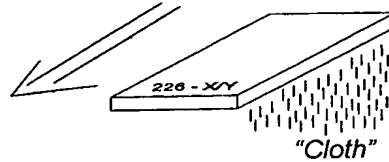
Before application of mixture, the substrates were rotated for a few seconds. This for "throwing off" particles.

SPINNER: 4000 r/m for 30 sec. Solution dropped on substrate, then rotated after less then 1 second.

ALIGNMENT:

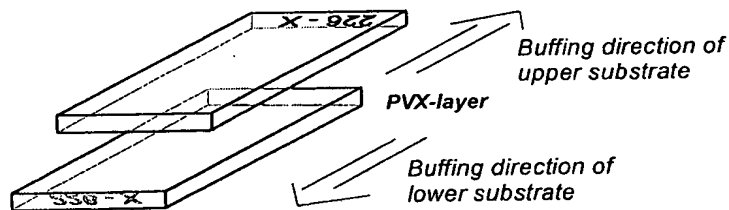
PRETREATMENT: Substrates heated to +120°C for 15 minutes in oven, then taken out to cool.

BUFFING: The substrate was buffed 5 times, with a pressure of 2 on a scale of 5. Buffing direction of substrate:



POST HEATING: The substrates were again heated; 10 minutes at about +70°C on a hot plate. Then taken off to cool.

CELL ASSEMBLY: 4µm spacer (glass fibre) in NOA 68 (exp. 1/5 2003). Lavender tip, 1.5 bar pressure. Exposed in UV-light under vacuum pressure for 7 minutes. Direction of the substrates in the cell:



SEALING OF CELL SIDES: The sides, the joint of the substrates, strengthened by applying NOA68 glue. Exposed under UV-light for 14 minutes.

FINAL CLEANING: The outside of the substrates were carefully cleaned with a "tops" with a small amount of Aceton.

ELECTRIC CONNECTIONS: U/S-soldered with "143°-lead"; Heat: 3, Sonic Power: 3. Cord with 105mm length (ELFA 55-241-52).

U.S. Serial No. 10/562,050
Declaration under 37 C.F.R. 1.131

EXHIBIT 3

Innehåll i denna loggbok:

76 sidor

Johan Felix

EC SIBEO

307-7 G/H (BHL 444) Buffered. Cell filled with MLC 6884. Excellent planar alignment. Not proper for VA-mode.

307-7 A/B (BHL 444) not Buffered. Again planar alignment of MLC 6884. Not appropriate for VA-mode.

307-7 I/K/L (BHL 444) ~~not~~ Buffered - Nice homeotropic alignment when filled with MLC 6884. Short response time for VA
 $\tau_r = 2.9 \text{ ms}$ $\tau_d = 4 \text{ ms}$
 $\tau_r + \tau_d = 6.9 \text{ ms}$

19.02.03

307-1 A/B (BHL 443) no buffer. Cell filled with A3. Shortage.

307-1 C/H (BHL 443) no buffer. Cell filled with A3. Shortage. Weak response.

307-1 I/J (BHL 443) no buffer. Cell filled with MLC 6884. Homeotropic alignment! VA mode response $\tau_r = 5 \text{ ms}$ $\tau_d = 8-9 \text{ ms}$

307-2 C/D (BHL 366) Buffered. Excellent VA-mode when filled with MLC 6884.

$\tau_r = 2.6 \text{ ms}$
 $\tau_d = 4.6 \text{ ms}$ Voltage - 4.5 V

$\tau_r + \tau_d = 7.2 \text{ ms}$

307-1 K/L BNL 443 - buffed. Cell filled with A mixture. First after filling - homeotropic alignment. After heating to the isotropic phase. Planar alignment (?) (May be with some pretilt at the surfaces). On applying an electric field - quadratic-like response. It seems that the field induces twist when the molecules of the nematic (A mixture) are forced to be parallel to the surface. The siloxane polymer then transfers its chiral properties on the nematic. Thus, a helix in the nematic takes place.

310-1 A/B (BNL 427 (alignment layer), BNL 443) - buffed. Cell filled with A mixture. Only a quadratic electro-optical response.

310-1 K/L (BNL 427 / BNL 443) - no buffing. Cell filled with A mixture. Bad alignment. Only a quadratic response.

310-3 A/B (BNL 444) - buffed. Cell filled with N4 (Merck) (low $\Delta\epsilon \approx 0.2$). Not good homeotropic alignment. In the places where the homeotropic alignment was good it was measure response times: $T_r = 13 \mu s$ and $T_d = 7 \mu s$ at 12V.

310-3 C/D (BNL 444) - buffed. Cell filled with Nematic phase 4 (A7) (Merck). L1BBA. Excellent homeotropic alignment. Measured response time

6608
6608



7

1

1

2

4

315-1 E/F - 462(Si), (A) mixt.

Very pronounced switching but quadratic. why reversed siloxane? maybe.

316-1 A/B - 444 (rubbed +) filled with MBBA mixt. at 60 \rightarrow 12-13 ms fall time

316-1 K/L - 444 (rubbed +) thinner film - filled with MBBA mixture \rightarrow 60 - 13 ms fall time. The film 444 may be is still thick. To decrease the thickness further.

28.04.03

315-4 C/D - 464 (parallel az_0^*) - cell filled with DF1 achiral SmC - linear response.

315-7 E/F - 464 (parallel az_0^*) cell filled with Dabrowski - no any linear response

315-7 G/H - 464 (parallel az_0^*) - cell filled with E7 - planar \rightarrow homeotropic: $T_r = 350 \mu s$
ec. induced transition
 $T_d = 4-5 \text{ ms}$

* 315-7 G/H - 464 (parallel rubbing az_0^*) cell filled with E7 - light induced transition planar to homeotropic at temp. near the N-Iso transition $\sim 58-60^\circ \text{C}$ (to check again)

315-7 I/J - 464 (parallel rubbing az_0^*) cell filled with Hoechst 908 - It gives partially in plane switching (depending on the orientation)

U.S. Serial No. 10/562,050
Declaration under 37 C.F.R. 1.131

EXHIBIT 4



Fax: +46 31 63 02 63
Phone: +46 31 63 02 00
Email: mail@awapatent.com

AWAPATENT AB
Box 11394
SE-404 28 GÖTEBORG
SWEDEN

Head office and registered office in Malmö. VAT No. SE556082702301

This message, which may contain confidential information, is intended only for the individual or entity to whom it is addressed. If you have received this message in error, please notify us immediately by telephone and return the original message to the above address by mail.

	No. of pages including this page: 49
Date:	2003-09-10
RECEIVER No:	031 - 82 70 35
Name/Firm:	Ecsibeo AB
Attention:	Johan Felix
Your ref:	IN-PLANE EC ALIGNMENT-P-SE
Our ref:	SE-21004686/Marie-Louise Jardle

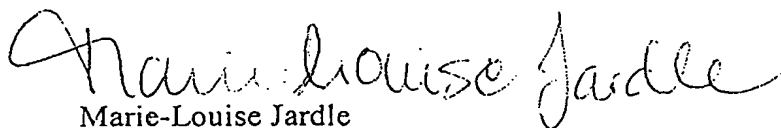
ECSIBEO AB
Er referens: IN-PLANE EC ALIGNMENT-P-SE
Ny patentansökan i SVERIGE

Hej Johan!

Här kommer enligt överenskommelse det uppdaterade ansökningsförslaget. Hör av dig när ni har läst igenom det.

Med vänliga hälsningar

AWAPATENT AB


Marie-Louise Jardle

If you do not receive a clear copy or the correct number of pages,
please inform us immediately.

A LIQUID CRYSTAL DEVICE AND A METHOD FOR MANUFACTURING
THEREOF

Technical field

The present invention generally relates to the field of liquid crystals. More specifically, the present invention relates to a liquid crystal device including a liquid crystal bulk layer presenting a surface director at a bulk surface thereof, and a surface-director alignment layer arranged to interact with the bulk layer at said bulk surface for obtaining a preferred orientation of the surface director of the bulk layer.

The invention also relates to a method for manufacturing a liquid crystal device and a method of controlling a liquid crystal bulk layer.

Technical background (I huvudsak samma som tidigare, förutom tillägg angående in-plane switching och problemdefinitionen som är markerade. Ny Fig 3 som visar prior art in-plane switching tas lämpligen med.)

Liquid crystals, widely used at present as electro-optical media in display devices, are organic materials with anisotropic physical properties. Liquid crystals are made of long rod-like molecules which have the ability to align along their long axis in a certain direction (orientation). The average direction of the molecules is specified by a vector quantity and is called director.

The operation of the liquid crystal displays is based on the changes of the optical characteristics, such as light transparency, light absorption at different wavelengths, light scattering, birefringence, optical activity, circular dichroism, etc, of the liquid crystal in the display caused by an applied electric field (direct coupling).

One of the basic operational principle of liquid crystal displays and devices is the switching of the orientation of the liquid crystal molecules by an applied electric field that couples to the dielectric anisotropy of the liquid crystal (dielectric coupling). Such a coupling gives rise to an electro-optic response quadratic with the applied electric field, i.e. independent of the field polarity.

There exist a number of different types of LCDs whose operation is based on dielectric coupling, especially dynamic scattering displays, displays using deformation of homeotropically aligned nematic liquid crystal, Schadt-Helfrich twisted nematic (TN) displays, super twisted nematic (STN) displays, in-plane switching (IPS) nematic displays, etc.

For modern applications, a LCD should possess several important characteristics, such as a high contrast and brightness, a low power consumption, a low working voltage, short rise (switching) and decay (relaxation) times, a low viewing angle dependence of the contrast, a grey scale or bistability, etc. The LCD should be cheap, easy to produce and to work with. None of the prior-art LCDs is optimised concerning all the important characteristics.

Nematics are the simplest structure of the liquid crystals which is formed when the liquid crystal molecules align themselves toward a particular direction in space.

In most of the conventional nematic liquid crystal displays, operating on the basis of the dielectric coupling, the electric field is applied normally to the liquid crystal bulk layer (i.e. normally to the confining substrates) and the liquid crystal bulk molecules are switched by the electric field in a plane perpendicular to the confining substrate surfaces (so-called out-of-plane switching). These displays are usually slow, and

nearly all suffer from non-satisfactory angular dependence of the contrast.

There is also another type of LCDs with in-plane switching, in which the electric field is applied along the liquid crystal bulk layer (i.e. in parallel with the confining substrates) and the liquid crystal bulk molecules are switched in a plane in parallel with the confining substrate surfaces. These displays exhibit a very small angular dependence of the image contrast but the resolution and the switching times are not satisfactory.

In the displays discussed above, the desired initial alignment of the liquid crystal layer in the absence of an external field, such as an electric field, is generally achieved by appropriate surface treatment of the confining solid substrate surfaces. The initial liquid crystal alignment is defined by solid surface/liquid crystal interactions. The orientation of the liquid crystal molecules adjacent the confining surface is transferred to the liquid crystal molecules in the bulk via elastic forces, thus imposing essentially the same alignment to all liquid crystal bulk molecules.

The director of the liquid crystal molecules near the confining substrate surface(s) (herein also called surface director) is constrained to point in a certain direction, such as perpendicular to (also referred to as homeotropic or vertical) or in parallel with (also referred to as homogeneous or planar) the confining substrate surface(s). The type of alignment in liquid crystal displays operating on the coupling between liquid crystal dielectric anisotropy and applied electric field is chosen in accordance with the sign of the dielectric anisotropy and the direction of the electric field and the desired type of switching mode (in-plane or out-of plane).

In out-of-plane switching liquid crystal cells employing a liquid crystal bulk having a negative dielectric anisotropy, it is important to uniformly orient the director of the liquid crystal bulk molecules (in the

field-off state) vertically to the substrate surfaces (so-called homeotropic alignment). An example of a method for establishing a homeotropic alignment comprises coating the confining substrate surfaces with a surfactant, such as lecithin or hexadecyltrimethyl ammonium bromide. The coated substrate surfaces is then also preferably rubbed in a predetermined direction, so that the field-induced planar alignment of the liquid crystal molecules will be oriented in the predetermined rubbing direction.

10 In out-of-plane switching liquid crystal cells employing a liquid crystal bulk having a positive dielectric anisotropy, it is important to uniformly orient the director of the liquid crystal bulk molecules (in the field-off state) in parallel with the substrate surface(s) (so-called homogeneous alignment). For twisted nematic liquid crystal cells, it is also important to orient the liquid crystal bulk molecules at a certain inclined orientation angle (tilt angle) to the substrate. Known methods for establishing homogeneous alignment is, for instance, the inorganic film vapour deposition method and the organic film rubbing method.

20 In the inorganic film vapour deposition method, an inorganic film is formed on a substrate surface by vapour-depositing an inorganic substance, such as silicon oxide, obliquely to the confining substrate so that the liquid crystal molecules are oriented by the inorganic film in a certain direction depending on the inorganic material and evaporation conditions. Since operation efficiency is low, this method is practically not used.

30 According to the organic film rubbing method, an organic coating of, for instance, polyvinyl alcohol, polyoxyethylene, polyamide or polyimide, is formed on a substrate surface, the coating is then baked, generally at 200-300°C, and the surface is thereafter rubbed in a predetermined direction using a cloth of e.g. cotton, nylon or polyester, so that the liquid crystal molecules will be oriented in the rubbing direction. Polyimide is most

often used due to desired chemical stability, thermal stability, etc.

5 In in-plane switching liquid crystal cells employing a liquid crystal bulk having a positive or negative dielectric anisotropy, it is important to uniformly orient the director of the liquid crystal bulk molecules in parallel with the substrate surfaces. The aligning methods used in this case are similar to those used for out-of-plane switching of liquid crystal cells employing a liquid crystal bulk having a positive dielectric anisotropy.

10 In in-plane switching liquid crystal cells employing a liquid crystal bulk having a positive dielectric anisotropy, the initial field-off planar alignment of the liquid crystal bulk molecules is perpendicular to the direction of the applied electric field.

15 In in-plane switching liquid crystal cells employing a liquid crystal bulk having a negative dielectric anisotropy, the initial planar alignment of the liquid crystal bulk molecules is along the direction of the applied electric field.

20 In all of the above disclosed methods of aligning the director of the liquid crystal bulk molecules near the confining substrate(s), a so-called surface-director alignment layer is generally applied on the confining substrate surface(s) facing said liquid crystal bulk.

25 It may be noted, that in the prior art (e.g. in US 2002/0006480) alignment layers of materials having mesogenic groups in their structure have been described. This type of layers is primarily used to increase the interaction between the alignment layer and the (mesogenic) liquid crystal bulk layer in the field-off state, but the alignment layer is not substantially affected by an applied electric field (i.e. it is not directly controllable by an electric field). Korrekt??

30 In the prior of art, there are in principal three different techniques for changing the optical performance of liquid crystals by accomplishing a new molecular ori-

35

Ja.

entation of the liquid crystals that differs from the initial alignment.

The first, most widely used technique for reorienting the molecules is to apply an external electrical field over the entire bulk liquid crystal layer. Due to direct coupling between the electric field and some of the liquid crystal material parameters, such as dielectric anisotropy, the field will directly reorient the liquid crystal bulk molecules in a new direction if their initial alignment does not correspond to a minimum energy of interaction of the electric field with the liquid crystal bulk.

The second known technique for reorienting the molecules of a liquid crystal layer is to design one or both of the confining alignment surfaces as a photo-controlled "command surface". Such a photo-controlled command surface is capable, when subjected to, for instance, UV light, to change the direction of alignment imposed by the surface on the liquid crystal molecules in contact with the surface. The concept of "photo commanded surface" has been described by K. Ichimura in a number of papers overviewed in Chemical Reviews, 100, p.1847 (2000). More specifically, an azobenzene monolayer is deposited onto the inner substrate surface of a sandwich cell containing a nematic liquid crystal layer. The azobenzene molecules change their conformation from "trans" to "cis" under illumination with UV light. The azobenzene molecules are anchored laterally to the substrate surface by the aid of triethoxysilyl groups. The trans-isomer of azobenzene moieties imposes a homeotropic alignment of the nematic liquid crystal, whereas the cis-isomer gives a planar orientation of the liquid crystal molecules. Hence, the conformational changes of the molecules in the alignment layer caused by the UV illumination will result in a change of the alignment of the nematic liquid crystal molecules. The relaxation to the initial alignment is obtained by illuminating the sample

with VIS-light or simply by heating it to the isotropic state.

The third known principle for reorientating liquid crystal molecules involves the use of so-called Electrically Commanded Surfaces (ECS). This principle is described in the published International patent application No. WO 00/03288. The ECS principle is used to primarily control a ferroelectric liquid crystalline polymer layer. According to ECS principle, a separate thin ferroelectric liquid crystalline polymer layer is deposited on the inner surfaces of the substrates confining a liquid crystal bulk material in a conventional sandwich cell. The ferroelectric liquid crystalline polymer layer acts as a dynamic surface alignment layer imposing a planar or substantially planar alignment on the adjacent liquid crystal bulk material. More specifically, when applying an external electric field across the cell - and thereby across the surface alignment layer - the molecules in the separate ferroelectric liquid crystalline polymer layer will switch. This molecular switching in the separate polymeric layer will, in its turn, be transmitted into the bulk volume via elastic forces at the boundary between the separate alignment layer and the bulk layer, thus resulting in a relatively fast in-plane switching of the bulk volume molecules ^{mediated} ~~induced~~ by the dynamic surface alignment layer. The ECS layer should be very thin (100-200 nm), and should preferably be oriented in bookshelf geometry, i.e. with smectic layers normal to the confining substrates. Furthermore, in order to keep the ECS layer and its operation intact, the material of ECS layer must be insoluble in the liquid crystal bulk material.

To optimise the performance of liquid crystal devices, it is desirable to decrease the total time period needed to switch and relax the liquid crystal bulk molecules in response to an applied external field. The total response time consists of a rise time (switching of the liquid crystal molecules to a field-induced orientation

state) and a decay time (relaxation of the liquid crystal molecules to a field-off orientation state). In prior art liquid crystal devices, the rise time is generally about 1/3 of the total response time. Hence, the decay time is generally about 2/3 of the total response time. *Stämmer detta både för in-plane och out-of-plane?*

The decay time of prior art out-of-plane switching nematic liquid crystal devices is generally about 20-100 ms resulting in a low image quality, in particular for moving images. The problem of long decay times is especially pronounced for liquid crystal devices having large display areas, and in more particular for out-of-plane switching liquid crystal devices. The rise time of an out-of-plane switching liquid crystal device can be rather easily adjusted to a desired value by the application of an appropriate field strength over the liquid crystal cell.

Liquid crystal devices having long rise times also results in a low image quality, in particular for moving images. The problem of long rise times is ^{advantage problems} especially pronounced for liquid crystal devices having large display areas, and in more particular for in-plane switching liquid crystal devices. In-plane switching of the surface-director of the liquid crystal molecules is somewhat restrained, and thus slowed down, by the substrate surfaces.

The rise time of prior art in-plane switching nematic liquid crystal devices is generally about 10-20 ms. *Korrekt?*

Fig 1 schematically shows an out-of-plane switching liquid crystal device 1 including a liquid crystal bulk layer 2 having a negative dielectric anisotropy ($\Delta\epsilon < 0$) between confining substrates 3. In the field-off state ($E = 0$), the liquid crystal bulk molecules are vertically aligned, via elastic forces, by a conventional surface-director alignment layer (not shown) applied on the confining substrate surfaces 3. When an external electric

generally
decay time
is longer,
such as...

Ja!

and thus
long
total
response
times.

Ja!

5ms total

field is applied ($E \neq 0$) across the liquid crystal bulk layer 2 between electrodes 4 on the confining substrates 3, the liquid crystal molecules 2 are switched to a field-induced planar orientation. However, the liquid crystal molecules 2 located near the confining substrate surfaces 3 are not only affected by the applied electric field, but also by the surface-director alignment layer, which result in an elastic deformation D1 of the liquid crystal layer 2 near the substrate surfaces 3, as shown in Fig 1. After removal of the external field, the liquid crystal molecules 2 near the surface-director alignment layer relax to their initial field-off orientation, due to the solid surface/liquid crystal interactions. The relaxation of the liquid crystal molecules 2 in this region affects, via elastic forces, the orientation of the more remote liquid crystal bulk molecules 2. Thus, the elastic deformation D1 that takes place in the liquid crystal layer 2 under an applied electric field disappears and the initial uniform field-off homeotropic alignment of the entire liquid crystal bulk layer 2 is finally restored. However, as mentioned above, the relaxation to field-off orientation is rather slow.

The same type of problem is illustrated for the out-of-plane switching liquid crystal device 1' shown in Fig 2, said device 1' including a liquid crystal bulk layer 2' having a positive dielectric anisotropy ($\Delta\epsilon > 0$) between confining substrates 3' coated with a conventional surface alignment layer (not shown). In the field-off state ($E = 0$), the liquid crystal bulk molecules 2' exhibit a planar alignment. When an external electric field is applied ($E \neq 0$) across the bulk liquid crystal layer 2' between electrodes 4' on the confining substrates 3', the liquid crystal molecules 2' are switched to a field-induced vertical orientation. An elastic deformation D2 of the liquid crystal layer 2' near the substrate surfaces 3' is shown in Fig 2.

Fig 3 schematically shows an in-plane switching liquid crystal device 1'' including a liquid crystal bulk layer 2'' having a positive dielectric anisotropy ($\Delta\epsilon > 0$) between confining substrates 3''. In the field-off state ($E = 0$), the liquid crystal bulk molecules 2'' exhibit a planar alignment in a first orientation direction obtained, via elastic forces, by a surface-director alignment layer (not shown) applied on the confining substrate surfaces 3''. When an external electric field is applied ($E \neq 0$) along the bulk liquid crystal layer 2'' (i.e. in parallel with the confining substrates 3'') between electrodes 4'' placed as shown in Fig 1, the liquid crystal molecules 2'' are switched in-plane to a field-induced second orientation direction along the orientation of the electric field. However, the switching of the liquid crystal molecules 2'' will be restrained by the surface-director alignment layer, thus increasing the rise time. *Har ni en fig (motsvarande Fig 1 och 2 som visar prior art in-plane switching?)*

The same reasoning applies to an in-plane switching liquid crystal device including a liquid crystal bulk layer 2 having a negative dielectric anisotropy ($\Delta\epsilon < 0$).

Summary of the invention (I princip helt nytt stycke.)

In light of the above-mentioned drawback of the known liquid crystal displays, a general object of the present invention is to provide an improved liquid crystal device, an improved method for manufacturing a liquid crystal device, and an improved method of controlling a liquid crystal device. The invention is not directed to displays only, but is useful in many other liquid crystal devices.

According to a first aspect of the invention, there is provided a liquid crystal device including a liquid crystal bulk layer presenting a surface director at a bulk surface thereof, and a surface-director alignment layer arranged to interact with the bulk layer at said

bulk surface for obtaining a preferred orientation of the surface director of the bulk layer, wherein the liquid crystal bulk layer and the surface-director alignment layer each are directly controllable by an electric field via dielectric coupling.

In a first embodiment of the device according to the invention, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of opposite signs. This device makes it possible to shorten the total response time by shortening the decay time to below 20 ms, such as about 4-6 ms, and thus provide an improved image quality, in particular for moving images and large display devices. This effect is especially advantageous in out-of-plane switching liquid crystal devices.

In a second embodiment of the device according to the invention, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of same sign. This device makes it possible to shorten the total response time by shortening the rise time to below 15 ms (??), such as about 1-5 ms, and thus provide an improved image quality, in particular for moving images and large display devices. Vad kan rise time förkortas till...? This effect is especially advantageous in in-plane switching liquid crystal devices.

In a third embodiment of the device according to the invention, the surface-director alignment layer comprises regions, preferably separate structural parts of a compound, exhibiting dielectric anisotropies ($\Delta\epsilon$) of opposite signs. This device is believed to make it possible to shorten the total response time by shortening the rise time as well as the decay time. This effect is especially advantageous in in-plane switching liquid crystal devices.

According to a second aspect of the invention, there is provided a method for manufacturing a liquid crystal device comprising the steps of providing a surface-

(*) OMTW
(- Skolev
inte)

* are
switched
vid låga spänning

director alignment layer on an inner surface of at least one substrate, and sandwiching a liquid crystal bulk layer between two substrates, said liquid crystal bulk layer presenting a surface director at a bulk surface thereof and being directly controllable by an electric field via dielectric coupling, and said surface-director alignment layer being arranged to interact with the bulk layer at said bulk surface for obtaining a preferred orientation of the surface director of the bulk layer, wherein said surface alignment layer being directly controllable by an electric field via dielectric coupling.

According to a third aspect of the invention, there is provided a method of controlling a liquid crystal bulk layer comprising the step of aligning a liquid crystal bulk layer presenting a surface director at a bulk surface thereof by use of a surface-director alignment layer arranged to interact with the bulk layer at said bulk surface for obtaining a preferred orientation of the surface director of the bulk layer, wherein the liquid crystal bulk layer and the surface-director alignment layer each are directly controllable by an electric field via dielectric coupling.

Brief description of the drawings

Fig 1 shows a prior art out-of-plane switching liquid crystal device exhibiting an initial vertical alignment of the liquid crystal bulk layer.

Fig 2 shows a prior art out-of-plane switching liquid crystal device exhibiting an initial planar alignment of the liquid crystal bulk layer.

Fig 3 shows a prior art in-plane switching liquid crystal device. *Föreslagen ny figur (se beskrivning ovan)!*

Fig 4 shows an embodiment of an out-of-plane switching liquid crystal device according to the invention exhibiting an initial vertical alignment of the liquid

crystal bulk layer. In this embodiment, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of opposite signs.

Fig 5 and 6 illustrate the difference between the devices shown in Fig 1 and Fig 4, respectively, with regard to elastic deformation.

Fig 7 shows an embodiment of the liquid crystal device according to the invention exhibiting an initial planar alignment of the liquid crystal bulk layer. In this embodiment, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of opposite signs.

Fig 8 and 9 illustrate the difference between the devices shown in Fig 2 and Fig 7, respectively, with regard to elastic deformation.

Fig 10 shows a first embodiment of an in-plane switching liquid crystal device according to the invention. In this embodiment, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of opposite signs. *Föreslagen ny figure (se beskrivning nedan)!*

Fig 11 shows a second embodiment of an in-plane switching liquid crystal device according to the invention. In this embodiment, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of same sign. *Föreslagen ny figure (se beskrivning nedan)!*

Fig 12 shows the rise and decay times measured for a device according to the invention exhibiting an initial vertical alignment of the liquid crystal bulk layer.

Detailed description of the invention (*I princip ny text, men som bygger på den gamla. Därför är inte alla ändringar markerade.*)

The dielectric anisotropy ($\Delta\epsilon$) of a material having an ordered molecular structure possessing a structural anisotropy, such as a crystalline or a liquid crystalline

structure, is the difference between the dielectric constants measured in perpendicular and parallel direction, respectively, to the preferred molecular orientation in this material.

5 When an electric field is applied across a material exhibiting a positive dielectric anisotropy ($\Delta\epsilon > 0$), the molecules (or functional groups of the molecules) will align their long axis along (or substantially along) the direction of the electric field.

10 When an electric field is applied across a material exhibiting a negative dielectric anisotropy ($\Delta\epsilon < 0$), the molecules (or functional groups of the molecules) will align their long axis perpendicular (or substantially perpendicular) to the direction of the electric field.

15 The liquid crystal device according to the invention includes a liquid crystal bulk layer presenting a surface director at a bulk surface thereof, and a surface-director alignment layer arranged to interact with the bulk layer at said bulk surface for obtaining a preferred orientation of the surface director of the bulk layer, wherein the liquid crystal bulk layer and the surface-director alignment layer each are directly controllable by an electric field via dielectric coupling.

25 *1. Först kommer generell info som gäller alla utföringsformer*

The liquid crystal device preferably includes at least one confining substrate, such as two confining substrates, at said bulk surface(s).

30 The surface-director alignment layer is preferably applied on the inner surface(s) of said substrate(s) confining the liquid crystal bulk layer.

35 The preferred orientation of the surface director of the liquid crystal bulk layer is generally obtained by interaction with the surface-director alignment layer in the absence of an external field, such as an electric field.

The liquid crystal bulk layer comprises a liquid crystal material exhibiting a (non-zero) dielectric anisotropy and thus being directly controllable by an applied electric field via dielectric coupling

5 The surface-director alignment layer comprises a material exhibiting a (non-zero) dielectric anisotropy and thus being directly controllable by an applied electric field via dielectric coupling.

10 The liquid crystal bulk layer of the device according to the invention is preferably a nematic liquid crystal.

The liquid crystal bulk layer may comprise a nematic liquid crystal material having a uniform or deformed configuration. The uniform configuration could, for instance, be planar, homeotropic or tilted. The deformed structure could, for instance, be twisted (i.e. twisted nematic or cholesteric) or with splay and/or bent elastic deformation.

20 The nematic liquid crystals of the bulk layer may be achiral or chiral. *molecules*

Examples of suitable liquid crystal bulk layer materials having positive and negative dielectric anisotropies, respectively, are givenⁿ in relation to the preferred embodiments described below.

25 The material of the surface-director alignment layer may either present liquid crystal properties or it may not present liquid crystal properties.

Preferably, the material of the surface-director alignment layer is a liquid crystal material, such as a nematic or smectic liquid crystal material. (*) like disk. lining scalar order.

The material of the surface-director alignment layer may, for instance, be a polymeric material, such as a chemically modified polyvinylalcohol, polyimide, polysiloxane, polyacrylate, polymethacrylate, polyamide, polyester, polyurethane, etc.

35 The surface-director alignment layer may also comprise a modified solid material, such as a chemically

or induces a ~~new~~ interphase having LC properties.

Materialet
med förmåga
att inducera
högre ordning
i gränsskiktet

Gränsskiktet
samt är
en smectisk
LC induceras
av ytskiktet
behöver

modified gold surface, a chemically modified silicon dioxide surface or a chemically modified glass surface comprising silanol groups.

5 The surface-director alignment layer may be produced by first applying a coating of a polymer having reactive groups on a substrate surface, and thereafter chemically attaching desired functional groups to said polymer coating by reaction with the reactive groups of the polymer, thus providing a desired surface-director alignment
10 layer.

The surface-director alignment layer may also be produced by applying a coating of an already modified polymer on a substrate surface.

15 An alternative is to chemically attach desired functional groups to a non-polymeric substrate surface, such as a gold-coated substrate surface.

20 Examples of suitable surface-director alignment layer materials having positive and negative dielectric anisotropies, respectively, are given in relation to the preferred embodiments described below.

important
25 In this context, it shall be noted that the functional groups (i.e. chemical groups being directly controllable via dielectric coupling) of the surface-director alignment layer material should be free to move their molecular orientation as a direct consequence of the dielectric coupling. Thus, the physical interaction between the functional groups and the rest of the surface-director alignment layer material should preferably be ^{weak} minimized. A low degree of interaction may, for instance, be obtained by selecting a surface-director alignment layer material having a ^{weak physical} low intra-molecular interaction between the functional groups and the rest of the material or by sterically preventing such ^{physical} intra-molecular interaction, e.g. by the use of spacers between
30 the functional group and the rest of the material.
35

The device according to the invention is preferably either an out-of-plane switching or an in-plane switching liquid crystal device.

5 In an out-of-plane switching device according to the invention having an initial planar alignment, an orthogonal projection of said surface director (of the liquid crystal bulk layer) on the confining substrate(s), termed projected surface director, presents said preferred orientation in a geometrical plane in parallel with said
10 substrate(s), termed preferred planar orientation, and said bulk layer is directly controllable by an applied electric field to perform an out-of-plane switching of said preferred planar orientation of the projected surface director.

15 In an out-of-plane switching device according to the invention having an initial vertical alignment, an orthogonal projection of said surface director (of the liquid crystal bulk layer) on a geometrical plane perpendicular to said substrate(s), termed projected surface
20 director, presents said preferred orientation, termed preferred vertical orientation, and said bulk layer is directly controllable by an applied electric field to perform an out-of-plane switching of said preferred vertical orientation of the projected surface director.

25 In out-of-plane switching devices according to the invention, the electric field is applied normally to the confining substrate(s) (i.e. normally to the liquid crystal bulk layer).

30 In in-plane switching devices according to the invention, an orthogonal projection of said surface director (of the liquid crystal bulk layer) on said substrate(s), termed projected surface director, presents said preferred orientation in a geometrical plane in parallel with said substrate, termed preferred planar orientation,
35 and said bulk layer is directly controllable by an applied electric field to perform an in-plane switch-

ing of said preferred planar orientation of the projected surface director.

In in-plane switching devices according to the invention, the electric field is applied in parallel with the confining substrate(s) (i.e. along the liquid crystal bulk layer).

2. Här kommer beskrivning av utföringsformer med olika tecken på den dielektriska anisotropin

Opposite signs of dielectric anisotropy
(Detta stycke motsvarar i princip tidigare inlämnad ansökan.)

In a first group of embodiments of the device according to the invention, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of opposite signs.

Fig 4 shows an embodiment of an out-of-plane switching liquid crystal device 5 according to the invention, wherein surface-director alignment layers 6 are applied on the inner surfaces of substrates 7 confining a liquid crystal bulk layer 8. The liquid crystal bulk 8 exhibits a negative dielectric anisotropy ($\Delta\epsilon < 0$) and the surface-director alignment layers 6 exhibit a positive dielectric anisotropy ($\Delta\epsilon > 0$).

The molecules (or the functional groups of the molecules) of the surface-director alignment layers 6 have in this embodiment an initial vertical orientation in relation to the confining substrate surfaces 7, thus resulting in vertically or substantially vertically aligned liquid crystal bulk molecules 8 in the field-off state ($E = 0$). The surface-director alignment layers 6 are also preferably unidirectionally rubbed to obtain a preferred orientation of a field-induced planar alignment.

It shall be noted that even though the device 5 shown in Fig 4 comprises two surface-director alignment layers 6 (two-sided embodiment), the device according to the invention may alternatively comprise, for instance,

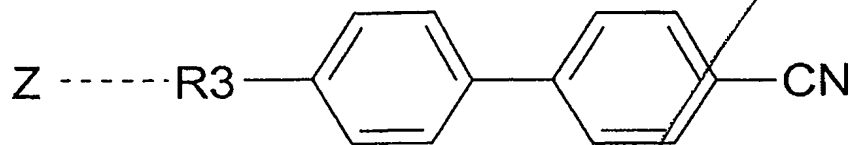
only one surface-director alignment layer (one-sided embodiment).

When an external electric field is applied ($E \neq 0$) normally to the liquid crystal bulk layer 8 between electrodes 9 on the confining substrates 7, the liquid crystal bulk molecules 8 aligned vertically or substantially vertically will, due to their negative dielectric anisotropy, switch out-of-plane to a field-induced planar orientation. The molecules (or functional groups of the molecules) of the surface-director alignment layers 6 will, however, keep their initial vertical orientation which will be enhanced and stabilized by the applied field due to their positive dielectric anisotropy. In other words, the molecules (or the functional groups of the molecules) of the surface-director alignment layers 6 will not switch when an electric field is applied across the layers 6, thus causing a strong elastic deformation D2 of the liquid crystal layer 8 near the substrate surface 7. When the external field is removed ($E = 0$), the vertically oriented molecules (or functional groups of the molecules) of the surface-director alignment layers 6 will promote a fast relaxation from the field-induced planar orientation of the liquid crystal bulk molecules 8 back to their field-off vertical orientation. Thus, the elastic deformation D3 shown in Fig 3 is stronger than the elastic deformation D1 shown in Fig 1, and therefore the relaxation to the field-off orientation will in this case be faster than in the case shown in Fig 1. The comparison of D1 and D3, respectively, is also schematically shown in Fig 5 and Fig 6, respectively.

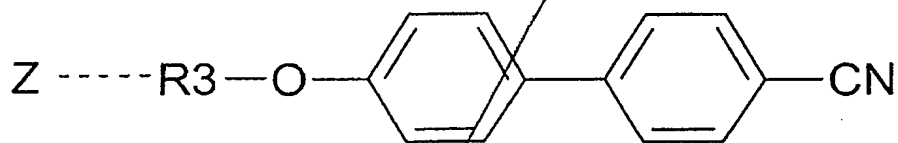
The liquid crystal bulk layer 8 may have a negative dielectric anisotropy within the range of from -6 to -1, and the surface-director alignment layer(s) 6 may have a positive dielectric anisotropy within the range of from 1 to 30.

Examples of surface-director alignment layer materials having a positive dielectric anisotropy, and being

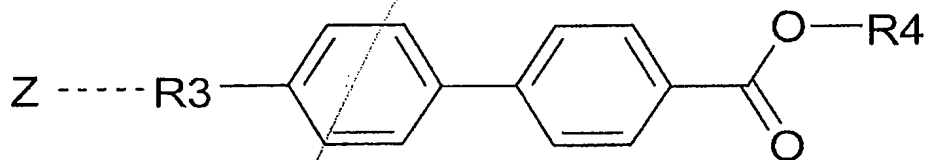
suitable in the above described embodiment, are modified polymers having functional groups selected among the structures of Formulas I to V chemically bonded to the polymer main chain (Z):



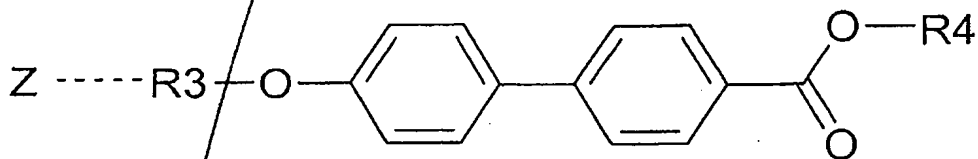
Formula I



Formula II

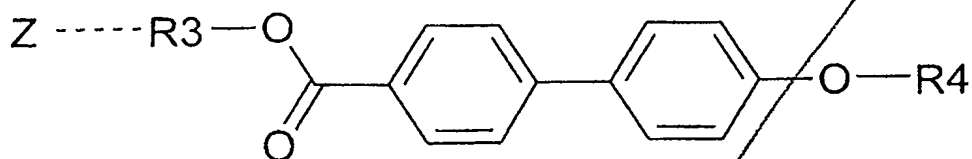


Formula III



Formula IV

1a mod
 structure
 (Benzil structure)
 interesting!



Formula V

wherein

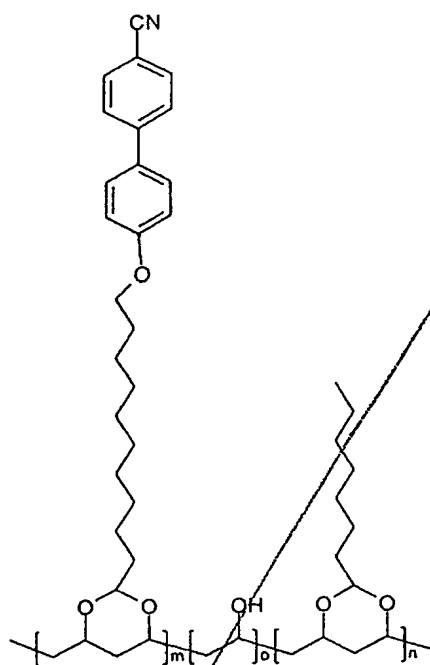
R3 is a hydrocarbon chain comprising 4 to 20 carbon atoms (it shall be noted that the number of carbon atoms may vary along the polymer main chain),

R4 is an alkyl group having 1 to 5 carbon atoms, and Z is part of a polymer main chain.

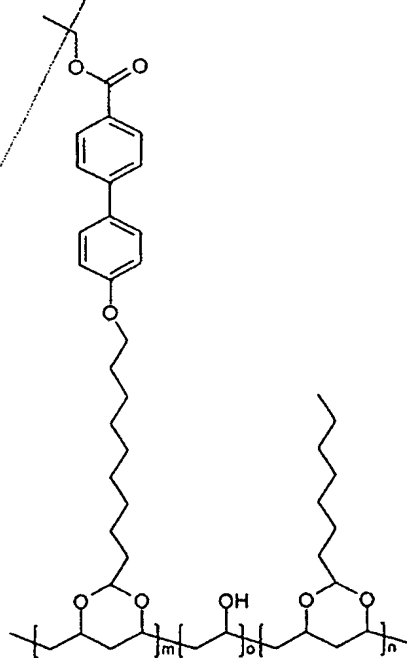
Instead of using a polymer, the functional groups of formula I to V can be chemically attached, as known to persons skilled in the art, to a solid surface, such as a gold surface, a silicon dioxide surface or a glass surface comprising silanol groups, to form a suitable material for use as the surface-director alignment layer according to the invention.

Said functional groups of the surface-director alignment layer having a positive dielectric anisotropy are preferably mesogenic groups. It is believed that it, in some cases, might be advantageous if said mesogenic groups is capable of forming a smectic liquid crystalline phase.

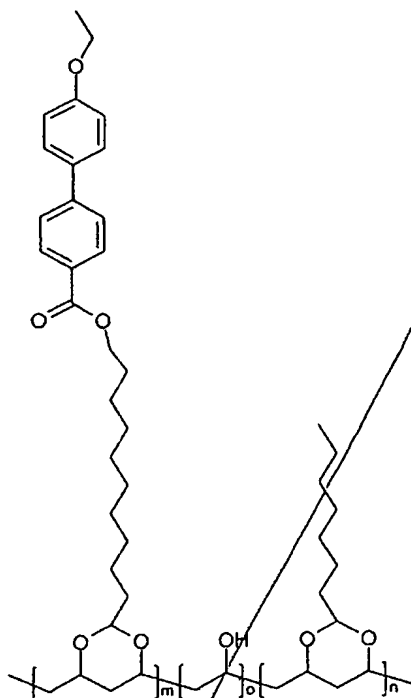
Specific examples of surface-director alignment materials having a positive dielectric anisotropy, and being suitable in the above described embodiment, are represented by Formulas VI to VIII:



Formula VI



Formula VII



Formula VIII

wherein $(m+n)/o$ is within the range of from 25/50 to
 5 43/14, preferably above 40/20, such as 42/16, and m/n is
 within the range of from 9/1 to 1/9, preferably 3/1 to
 1/3, such as 2/1.

It shall be noted that in an embodiment of an out-
of-plane switching device according to the invention
 10 comprising two surface-director alignment layers applied
 on substrate surfaces confining the liquid crystal bulk
 layer, and wherein the surface-director alignment layer
 exhibit a positive dielectric anisotropy and the liquid
 crystal bulk layer exhibit a negative dielectric
 15 anisotropy, the dipole moments of the functional groups
 of each surface-director alignment layer may either have
 the same direction or opposite directions.

Such a device having two separate alignment layers
 exhibiting the same directions of dipole moments is
 20 exemplified by a device having two separate alignment

layers of the material according to Formula VI (or Formula VII).

Such a device having two separate alignment layers exhibiting the opposite directions of dipole moments is exemplified by a device having one alignment layer of the material according to Formula VI (or Formula VII) and one alignment layer of the material according to Formula VIII.

Examples of liquid crystal bulk layer materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are a mixture of MLC 6608 ($\Delta\epsilon = -4.2$) and MBBA ($\Delta\epsilon = -0.8$), a mixture of MLC 6684 ($\Delta\epsilon = -5.0$) and MBBA ($\Delta\epsilon = -0.8$), and a mixture of MDA 98-3099 ($\Delta\epsilon = -6$) and MBBA ($\Delta\epsilon = -0.8$), all of which are nematic liquid crystal materials supplied by Merck.

Fig 7 shows another embodiment of an out-of-plane switching liquid crystal device 10 according to the invention, wherein surface-director alignment layers 11 are applied on the inner surfaces of substrates 12 confining a liquid crystal bulk layer 13. The liquid crystal bulk 13 exhibits a positive dielectric anisotropy ($\Delta\epsilon > 0$) and the surface-director alignment layers 11 exhibit a negative dielectric anisotropy ($\Delta\epsilon < 0$).

The molecules (or the functional groups of the molecules) of the surface-director alignment layers 11 have in this embodiment an initial planar orientation in relation to the confining substrate surfaces 12, thus resulting in planar or substantially planar aligned liquid crystal bulk molecules 13 in the field-off state ($E = 0$). The surface-director alignment layers 11 is also preferably unidirectionally rubbed to obtain a preferred orientation of the planar alignment (in field-off state).

It shall be noted that even though the device 10 shown in Fig 7 comprises two surface-director alignment layers 11 (two-sided embodiment), the device according to the invention may alternatively comprise, for instance,

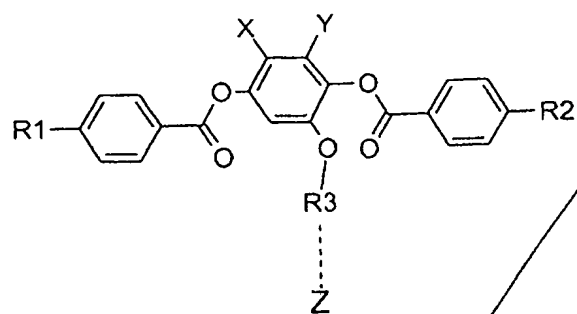
only one surface-director alignment layer (one-sided embodiment).

When an external electric field ($E \neq 0$) is applied normally to the liquid crystal bulk layer 13 between electrodes 14 on the confining substrates 12, the liquid crystal bulk molecules 13 aligned planar or substantially planar will, due to their positive dielectric anisotropy, switch out-of-plane to a field-induced vertical orientation. The molecules (or the functional groups of the molecules) of the surface-director alignment layers 11 will, however, keep their initial uniform planar orientation which will be enhanced and stabilized by their negative dielectric anisotropy. In other words, the molecules (or the functional groups of the molecules) of the surface-director alignment layers 11 will not switch when an electric field is applied across the layers 11. When the external field is removed ($E = 0$), the planar oriented molecules (or the functional groups of the molecules) of the surface-director alignment layers 11 will promote a fast relaxation from the field-induced vertical orientation of the liquid crystal bulk molecules 13 back to their initial field-off planar orientation. Thus, the elastic deformation D4 shown in Fig 7 is stronger than the elastic deformation D2 shown in Fig 2. The comparison of D2 and D4 respectively, is also schematically shown in Fig 8 and Fig 9, respectively.

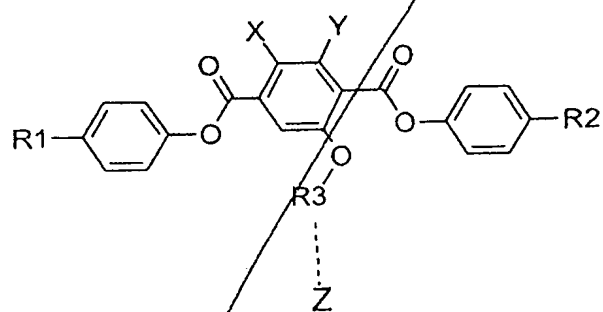
The liquid crystal bulk layer 13 may have a positive dielectric anisotropy within the range of from 1 to 30, and the surface alignment layer(s) 11 may have a negative dielectric anisotropy within the range of from -6 to -1.

Examples of surface-director alignment materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are modified polymers having functional groups selected among the structures of Formulas IX to XV chemically bonded to the polymer main chain (Z):

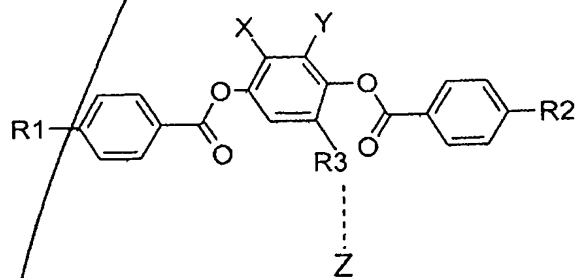
26



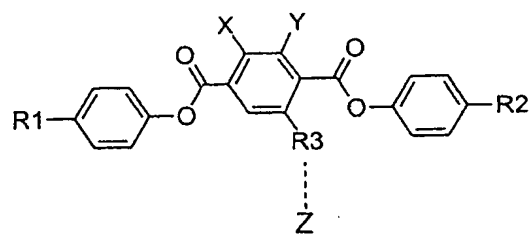
Formula IX



Formula X



Formula XI



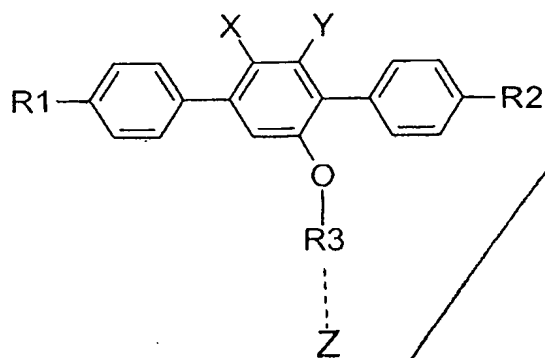
Formula XII

*Flex examples
in before*

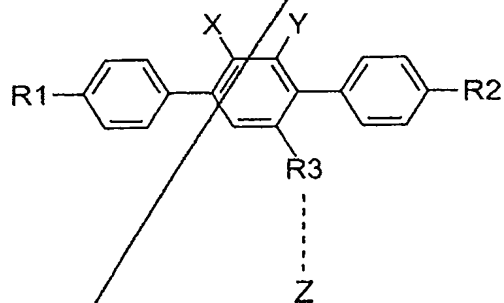
5

10

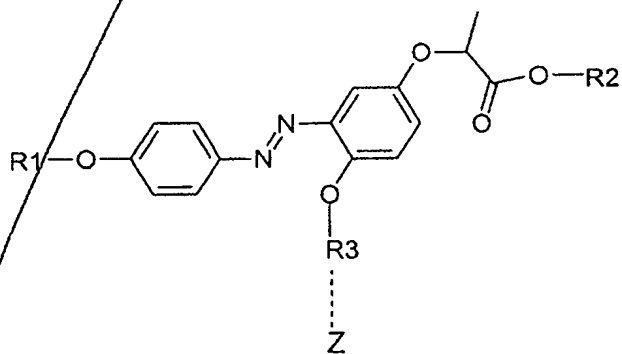
27



Formula XIII



Formula XIV



Formula XV

5

wherein

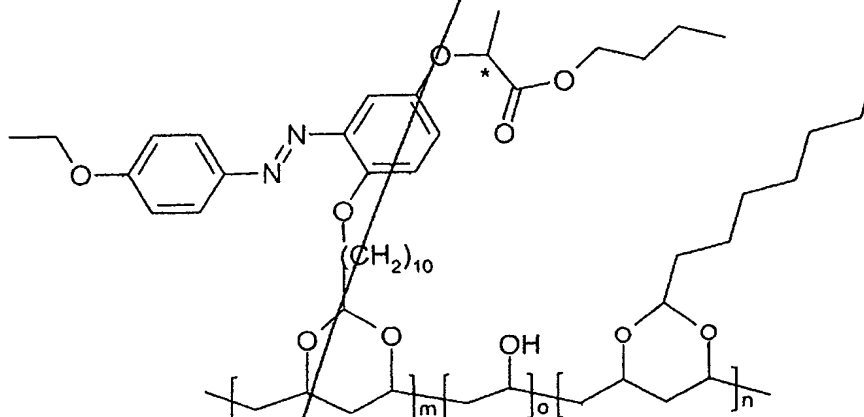
X and Y each independently are H, F, Cl, CN, or CF₃,R1 and R2 each independently are an alkyl ~~an~~10 ~~alkyl~~ group comprising 2 to 12 carbon atoms,

R3 is a hydrocarbon chain comprising 4 to 20 carbon atoms (it shall be noted that the number of carbon atoms may vary along the polymer main chain),

Z is part of a polymer main chain.

5 Instead of using a polymer, the functional groups of formula IX to XV can be chemically attached, as known to persons skilled in the art, to a solid surface, such as a gold surface, a silicon dioxide surface or a glass surface comprising silanol groups, to form a suitable
10 material for use as the surface-director alignment layer according to the invention.

Specific examples of surface-director alignment materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are represented by Formula XVI:
15



Formula XVI

wherein $(m+n)/o$ is within the range of from 25/50 to
20 43/14, preferably above 40/20, such as 43/18, and m/n is within the range of from 9/1 to 1/9, preferably 3/1 to 1/3, such as 1/1.

Examples of liquid crystal bulk layer materials having a positive dielectric anisotropy, and being suitable
25 in the above described embodiment, are E44 ($\Delta\epsilon = +16.8$), E9 ($\Delta\epsilon = ???$), and E70 A ($\Delta\epsilon = +10.8$), all of which are

nematic liquid crystal materials supplied by Merck. Vad är $\Delta\epsilon$ för E9)??

Här kommer ett tillägg avseende in-plane switching (olika tecken).

5 The embodiments shown in Fig 4 and 7 include out-of-
plane switching liquid crystal devices each device com-
prising a liquid crystal bulk layer and a surface-
director alignment layer exhibiting dielectric anisot-
ropies of opposite signs. It shall be noted that the com-
10 bination of a surface-director alignment layer and a liq-
uid crystal bulk layer exhibiting dielectric anisotropies
of opposite signs is also applicable and advantageous for
in-plane switching liquid crystal devices, even though
the effect of a decreased decay time is more pronounced
15 for out-of-plane switching liquid crystal devices. Thus,
the device according to the invention wherein the liquid
crystal bulk layer and the surface-director alignment
layer exhibit dielectric anisotropies of opposite signs
is preferably an out-of-plane switching liquid crystal
20 device. Korrekt?

Fig 10 shows an embodiment of an in-plane switching
liquid crystal device .. according to the invention,
wherein surface-director alignment layers .. are applied
on the inner surfaces of substrates .. confining a liquid
25 crystal bulk layer ... The liquid crystal bulk .. exhib-
its a positive dielectric anisotropy ($\Delta\epsilon > 0$) and the
surface-director alignment layers .. exhibit a negative
dielectric anisotropy ($\Delta\epsilon < 0$).

The molecules (or the functional groups of the mole-
30 cules) of the surface-director alignment layers .. have
in this embodiment an initial planar orientation, in a
first direction, in relation to the confining substrate
surfaces ..., thus resulting in planar or substantially
planar aligned liquid crystal bulk molecules .. in the
35 field-off state ($E = 0$). The surface-director alignment
layers .. is unidirectionally rubbed to obtain the pre-
ferred field-off first planar orientation direction.

It shall be noted that even though the device 10 shown in Fig 10 comprises two surface-director alignment layers .. (two-sided embodiment), the device may alternatively comprise, for instance, only one surface-director alignment layer (one-sided embodiment).

When an external electric field is applied ($E \neq 0$) along the liquid crystal bulk layer .. (in parallel with the confining substrates ..) between electrodes .. placed as shown in Fig 4, the liquid crystal bulk molecules .. will, due to their positive dielectric anisotropy, switch in-plane to a field-induced second planar orientation direction along the direction of the applied field. The molecules (or the functional groups of the molecules) of the surface-director alignment layers .. will, however, keep their initial first planar orientation direction which will be enhanced and stabilized by their negative dielectric anisotropy. In other words, the molecules (or the functional groups of the molecules) of the surface-director alignment layers .. will not switch when an electric field is applied along the layers ... When the external field is removed ($E = 0$), the molecules (or the functional groups of the molecules) of the surface-director alignment layers .. having the first planar orientation direction will promote a fast relaxation from the field-induced second planar orientation direction of the liquid crystal bulk molecules .. back to their initial field-off planar first orientation direction.

Examples of surface-director alignment materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are modified polymers having functional groups selected among the structures of Formulas IX to XV chemically bonded to the polymer main chain (Z).

Instead of using a polymer, the functional groups of Formulas IX to XV can be chemically attached, as known to persons skilled in the art, to a solid surface, such as a gold surface, a silicon dioxide surface or a glass sur-

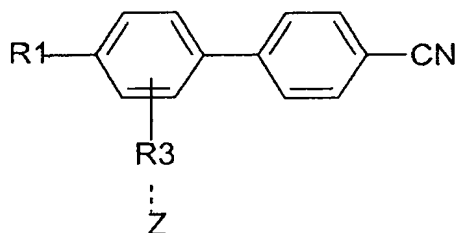
face comprising silanol groups, to form a suitable material for use as the surface-director alignment layer according to the invention.

Specific examples of surface-director alignment materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are represented by Formula XVI.

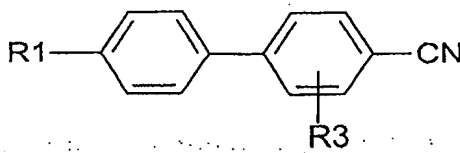
Examples of suitable liquid crystal bulk layer materials having a positive dielectric anisotropy, and being suitable in the above described embodiment, are E44 ($\Delta\epsilon = +16.8$), E9 ($\Delta\epsilon = ???$), and E70 A ($\Delta\epsilon = +10.8$), all of which are nematic liquid crystal materials supplied by Merck.

Another embodiment of an in-plane switching liquid crystal device according to the invention is a device comprising a liquid crystal bulk exhibiting a negative dielectric anisotropy ($\Delta\epsilon < 0$) and surface-director alignment layers exhibiting a positive dielectric anisotropy ($\Delta\epsilon > 0$).

Examples of surface-director alignment materials having a positive dielectric anisotropy, and being suitable in the above described embodiment, are modified polymers having functional groups selected among the structures of Formulas XVII to XXVIII chemically bonded to the polymer main chain (Z):

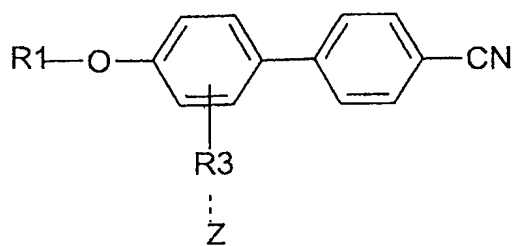


Formula XVII

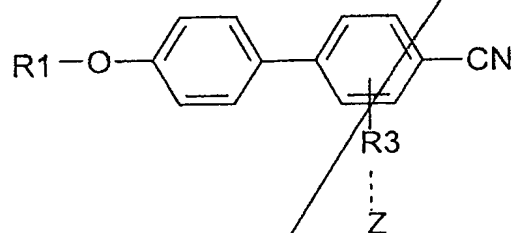


32

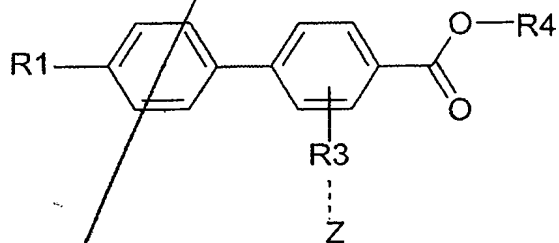
Formula XVIII



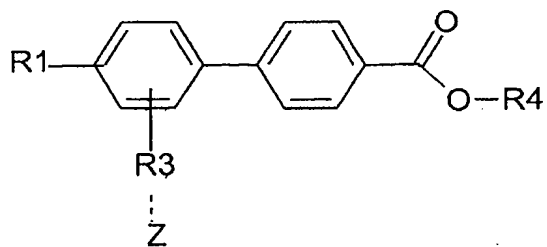
Formula XIX



Formula XX



Formula XXI

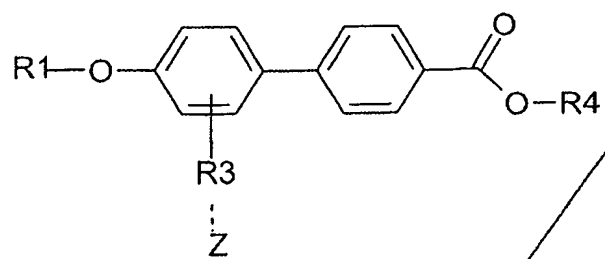


Formula XXII

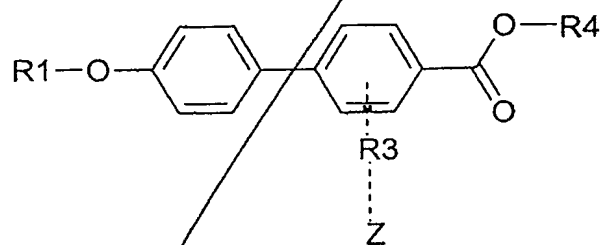
5

*Her
Example
as best*

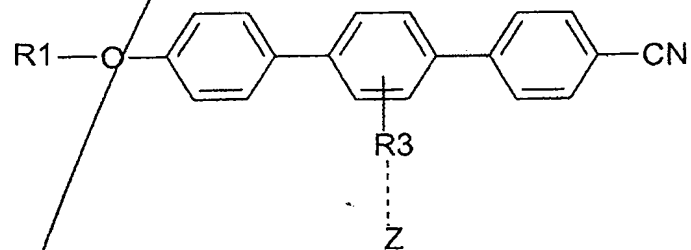
10



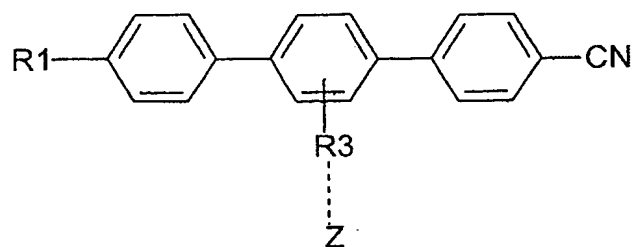
Formula XXIII



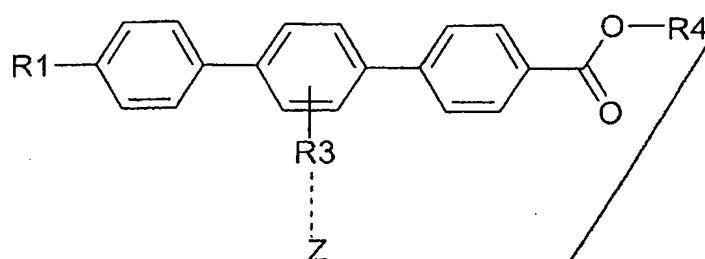
Formula XXIV



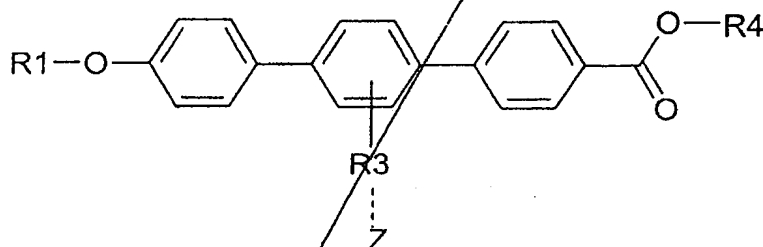
Formula XXV



Formula XXVI



Formula XXVII



Formula XXVIII

wherein

10 R1 is an alkyl or an alkoxy group comprising 2 to 12 carbon atoms. Är detta korrekt??? (Ej explicit angivet av Bertil.)

R3 is a hydrocarbon chain comprising 4 to 20 carbon atoms (it shall be noted that the number of carbon atoms may vary along the polymer main chain),

15 R4 is an alkyl group having 1 to 5 carbon atoms, and Z is part of a polymer main chain.

20 Instead of using a polymer, the functional groups of formula I to XII can be chemically attached, as known to persons skilled in the art, to a solid surface, such as a gold surface, a silicon dioxide surface or a glass surface comprising silanol groups, to form a suitable material for use as the surface-director alignment layer according to the invention.

Specific examples of surface-director alignment material having a positive dielectric anisotropy, and being suitable in the above described embodiment, are represented by Formulas ...: Har ni några specifika exempel???

5

Examples of liquid crystal bulk layer materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are a mixture of MLC 6608 ($\Delta\epsilon = -4.2$) and MBBA ($\Delta\epsilon = -0.8$), a mixture of MLC 6684 ($\Delta\epsilon = -5.0$) and MBBA ($\Delta\epsilon = -0.8$), and a mixture of MDA 98-3099 ($\Delta\epsilon = -6$) and MBBA ($\Delta\epsilon = -0.8$), all of which are nematic liquid crystal materials supplied by Merck. Ska det vara MLC-6684 eller MLC 6884 (vilket var angivet i Johans mail ang exakt anisotropivärde)..??

15

3. Här kommer beskrivning av utföringsformer med samma tecken på den dielektriska anisotropin

Same sign of dielectric anisotropy (Nytt avsnitt!)

$\Delta\epsilon_{yta} \gg \Delta\epsilon_{di}$

20

In a second group of embodiments of the device according to the invention, the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of same sign. Said device is preferably an in-plane switching liquid crystal device.

25

Fig 11 shows an embodiment of a in-plane switching liquid crystal device .. according to the invention, wherein surface-director alignment layers .. are applied on the inner surfaces of substrates .. confining a liquid crystal bulk layer ... Both the liquid crystal bulk .. and the surface-director alignment layers .. exhibit positive dielectric anisotropies ($\Delta\epsilon > 0$).

30

35

The molecules (or the functional groups of the molecules) of the surface-director alignment layers .. have in this embodiment an initial planar orientation, in a first direction, in relation to the confining substrate surfaces ..., thus resulting in ^{planarity}homogeneously or substantially homogeneously aligned liquid crystal bulk molecules .. in the field-off state ($E = 0$). The surface-

director alignment layers .. are unidirectionally rubbed to obtain the preferred field-off first planar orientation direction.

5 It shall be noted that even though the device .. shown in Fig 11 comprises two surface-director alignment layers .. (two-sided embodiment), the device according to the invention may alternatively comprise, for instance, only one surface-director alignment layer (one-sided embodiment).

10 When an external electric field is applied ($E \neq 0$) along the liquid crystal bulk layer .. (in parallel with the confining substrates ..) between electrodes .. placed as shown in Fig 11, the liquid crystal bulk molecules .. will, due to their positive dielectric anisotropy, switch
 15 in-plane to a field-induced second planar orientation direction along the direction of the applied field.

The molecules (or functional groups of the molecules) of the surface-director alignment layers .. will, also switch in-plane to a field-induced second orientation direction due to their positive dielectric anisotropy when an electric field is applied along the layer and in parallel with the confining substrates ... The in-plane switching molecules (or functional groups of the molecules) of the surface-director alignment layers ..
 20 will promote a fast switching from the field-off first planar orientation direction of the liquid crystal bulk molecules .. to their field-induced second planar orientation direction. Thus, the switching of the liquid crystal bulk molecules to the field-induced orientation di-
 25 rection will in this case be faster, than the in-plane switching of a prior art liquid crystal device having a non-switching surface director alignment layer (shown in Fig 3). In this context, it shall however be noted that the surface-director alignment layer of the device ac-
 30 cording to the invention does not induce the in-plane switching of the liquid crystal bulk molecules, which themselves are directly controllable via dielectric cou-
 35

at a lower applied field (voltage)

pling. The surface-director alignment layer merely facilitates said in-plane bulk switching. *För att poängtera skillanden gentemot ECS.*

The liquid crystal bulk layer .. may have a positive dielectric anisotropy within the range of from 1 to 30, and the surface-director alignment layer(s) .. may have a positive dielectric anisotropy within the range of from 1 to 30.

It is believed to be advantageous if the positive dielectric anisotropy of the surface-director alignment layer(s) is higher (more positive), preferably much higher, than the positive dielectric anisotropy of the liquid crystal bulk layer. *Korrekt? (Inte angivet då olika tecken.)*

Examples of surface-director alignment layer materials having a positive dielectric anisotropy, and being suitable in the above described embodiment, are modified polymers having functional groups selected among the structures of Formulas XVII to XXVIII chemically bonded to the polymer main chain (Z).

Instead of using a polymer, the functional groups of formula I to XII can be chemically attached, as known to persons skilled in the art, to a solid surface, such as a gold surface, a silicon dioxide surface or a glass surface comprising silanol groups, to form a suitable material for use as the surface-director alignment layer according to the invention.

Specific examples of surface-director alignment material having a positive dielectric anisotropy, and being suitable in the above described embodiment, are represented by Formulas ...:??? *Har ni några specifika exempel?*

In an in-plane switching liquid crystal device, according to the invention, having a surface-director alignment layer and a liquid crystal bulk layer exhibiting dielectric anisotropies of same sign, it may be advantageous to use two electrode ^{arrays} pairs arranged so that

near two

arrays
each consisting of

does not dir.

Jo

Figures
within the

the electric field obtainable between the first electrode pair is substantially perpendicular to the electric field obtainable between the second electrode pair. In this embodiment both the switching and the relaxation of the

5 liquid crystal bulk molecules occur in the presence of an applied electric field, and a short response time is easily attainable. Korrekt?? Vill ni ha med detta?

Another embodiment of an in-plane switching liquid crystal device according to the invention, is a device
10 wherein both the liquid crystal bulk layer and the surface-director alignment layer(s) exhibit negative dielectric anisotropies ($\Delta\epsilon < 0$). When an external electric field ($E \neq 0$) is applied along the liquid crystal bulk layer (i.e. in parallel with the confining substrates),
15 the liquid crystal bulk molecules will, due to their negative dielectric anisotropy, switch in-plane from a field-off first planar orientation direction to a field-induced second planar orientation direction perpendicular the direction of the applied electric field.

20 The molecules (or functional groups of the molecules) of the surface-director alignment layers will, also switch in-plane from a field-off first planar orientation direction to a field-induced second orientation direction due to their negative dielectric anisotropy
25 when an electric field is applied along the layer and in parallel with the confining substrates. The in-plane switching molecules (or functional groups of the molecules) of the surface-director alignment layers will thus promote a fast switching from the field-off first planar
30 orientation direction of the liquid crystal bulk molecules to their field-induced second planar orientation direction. Thus, the switching of the liquid crystal bulk molecules to the field-induced orientation direction will in this case be faster than the in-plane switching of a
35 corresponding prior art liquid crystal device having a non-switching surface director alignment layer. Also in this case, it shall be noted that the surface-director

alignment layer of the device according to the invention does not induce the in-plane switching of the liquid crystal bulk molecules, it merely facilitates said switching.

5 The liquid crystal bulk layer in this embodiment may have a negative dielectric anisotropy within the range of from -6 to -1, and the surface alignment layer(s) may have a negative dielectric anisotropy within the range of from -6 to -1.

10 It is believed to be advantageous if the negative dielectric anisotropy of the surface-director alignment layer(s) ^{larger negative value} is lower (more negative), preferably much lower, than the negative dielectric anisotropy of the liquid crystal bulk layer. Korrekt? (Inte angivet då olika tecken.)

15 Examples of surface-director alignment materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are modified polymers having functional groups selected among the
 20 structures of Formulas IX to XV chemically bonded to the polymer main chain (Z).

25 Instead of using a polymer, the functional groups of formula IX to XV can be chemically attached, as known to persons skilled in the art, to a solid surface, such as a gold surface, a silicon dioxide surface or a glass surface comprising silanol groups, to form a suitable material for use as the surface-director alignment layer according to the invention.

30 Specific examples of surface-director alignment materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are represented by Formula XVI.

35 Examples of liquid crystal bulk layer materials having a negative dielectric anisotropy, and being suitable in the above described embodiment, are a mixture of MLC 6608 ($\Delta\epsilon = -4.2$) and MBBA ($\Delta\epsilon = -0.8$), a mixture of MLC 6684 ($\Delta\epsilon = -5.0$) and MBBA ($\Delta\epsilon = -0.8$), and a mixture of

MDA 98-3099 ($\Delta\epsilon = -6$) and MBBA ($\Delta\epsilon = -0.8$), all of which are nematic liquid crystal materials supplied by Merck.

4. Här kommer beskrivning av utföringsformer med olika tecken på den dielektriska anisotropin inom orienteringsskiktet

Regions of the surface-director alignment layer exhibiting opposite signs of dielectric anisotropy

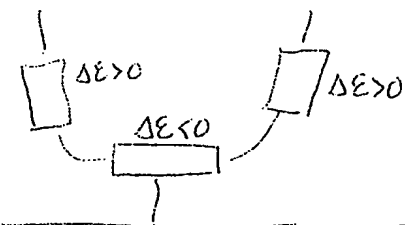
- In a third group of embodiments of the device according to the invention, the surface-director alignment layer comprises ~~regions~~ ^{structural parts} exhibiting dielectric anisotropies ($\Delta\epsilon$) of opposite signs. This type of device, preferably an in-plane switching liquid crystal device, is believed to provide a short decay time as well as a short rise time.

It is believed that said ~~regions~~ ^{structural parts} exhibiting dielectric anisotropies ($\Delta\epsilon$) of opposite signs preferably should be homogeneously distributed in the surface-director alignment layer. ??? Är detta troligt? Ja!

- A surface-director alignment layer comprising ~~regions~~ exhibiting dielectric anisotropies ($\Delta\epsilon$) of opposite signs is obtainable using, for instance, materials comprising dimeric chemical structures having a first structural part of positive dielectric anisotropy ($\Delta\epsilon > 0$) and a second structural part of negative dielectric anisotropy ($\Delta\epsilon < 0$). * Trimeric structures possible - one or more parts.

- Examples of surface-director alignment materials having a first structural part of positive dielectric anisotropy and a second structural part of negative dielectric anisotropy, and being suitable in the above described embodiment, are modified polymers having functional groups selected among the structures of Formulas XXIX chemically bonded to the polymer main chain (Z):

From liquid
in-plane
out-of-plane



Examples

A liquid crystal display glass substrate having a thickness of 1.10 mm was used. One side of the substrate had an ITO (indium tin oxide) layer (electrode material) with a surface resistance of $80 \Omega/\text{cm}^2$. The glass was cut into pieces with a size of 9,5 X 12,5 mm, and the edges were grinded.

The substrates were then washed several times in distilled water in an ultra-sonic bath, dried and then washed two times in isopropanol. The substrates were thereafter moved into a clean-room.

The ITO side of the substrates was spin coated with a surface-director alignment layer material, dissolved in THF to a concentration of about 0.1-0.5%. The speed was 3000-4000 rpm and coating was performed during 30 seconds.

After coating, the substrates were heated for approximately 5-10 minutes at a temperature of 125°C . Then the substrates were set to cool.

The applied surface-director alignment layer, on top of the ITO layer, was buffed with a velvet cloth. All substrates were buffed in the same direction. When the cell was put together, one substrate was rotated 180° , thus making the buffing direction parallel in the cell.

Two substrates were put together to a cell using UV-glue (Norland NOA68), and spacers at two edges. The cell was then put under pressure in a UV-exposure box for 15 minutes.

Small electric cords were ultra-sonically soldered to each ITO-surface of the cell.

A nematic bulk liquid crystal material was introduced into the cell in isotropic phase by means of capillary forces.

Example 1: Out-of-plane switching liquid crystal device having an electrically stabilised vertical alignment layer

The ITO side of the substrates was coated, as described above, with a polymer material according to Formula VI wherein $(m+n)/o$ is 42/16 and m/n is 2/1. It shall be noted, however, that any one of the structures according to Formula I to VIII may be used in this embodiment.

The polymer layer (about 100 nm) was rubbed unidirectionally very lightly to induced a small pretilt of the side mesogenic groups of the polymer, and the cell was thereafter assembled.

The sandwich cell (cell gap about 3 μm) was then filled with the nematic mixture MBBA/MLC6608 (Merck, Germany), 60/40 wt%, exhibiting $\Delta\epsilon < 0$.

In this cell, the polymer layer acts as a surface-director alignment layer.

The alignment of the cell after cooling to room temperature was inspected by means of a polarising microscope and it was found to be uniform vertical.

The response rise and decay times were measured in a set-up comprising a polarising microscope, a photo-detector, an oscilloscope and a puls generator.

The electro-optic response of the cell with vertical alignment, under application of unipolar impulses with low frequency (about 1 Hz), is depicted in Fig 9. At a voltage (U) of 9.2 V, the measured rise and decay time were about 2 and 4 ms, respectively. Thus, the measured decay time is about 5-10 times shorter than the decay time usually measured in out-of-plane switching liquid crystal cells with an initial vertical alignment.

Example 2: Out-of-plane switching liquid crystal device having an electrically stabilised planar alignment layer

The ITO side of the substrates was coated, as described above, with a polymer material according to

Formula XVI wherein $(m+n)/o$ is 43/18 and m/n is 1. It shall be noted, however, that any one of the structures according to Formula IX to XVI may be used in this embodiment.

5 The polymer layer (about 100 nm) was rubbed unidirectionally to ensure uniform planar alignment of the side mesogenic groups of the polymer, and the cell was thereafter assembled.

10 The sandwich cell (cell gap about 3 μm) was then filled with the nematic mixture E7 (BDH, UK) exhibiting $\Delta\epsilon > 0$.

 In this cell, the polymer layer acts as a surface-director alignment layer.

15 The alignment of the cell after cooling to the room temperature was inspected by means of a polarising microscope and it was found to be uniform planar.

 The rise and decay times were measured in a set-up comprising a polarising microscope, a photo-detector, an oscilloscope and a puls generator.

20 The electro-optic response of the cell with planar alignment, under application of unipolar impulses with low frequency (about 1 Hz), was found to be about 0.5 ms and 4 ms for rise and decay times, respectively.

25 *More Examples ???*

CLAIMS

1. A liquid crystal device including a liquid crystal bulk layer presenting a surface director at a bulk surface thereof, and a surface-director alignment layer arranged to interact with the bulk layer at said bulk surface for obtaining a preferred orientation of the surface director of the bulk layer, c h a r a c t e r i s - e d in that the liquid crystal bulk layer and the surface-director alignment layer each are directly controllable by an electric field via dielectric coupling.

2. A liquid crystal device according to claim 1, wherein the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of opposite sign.

3. A liquid crystal device according to claim 1, wherein the liquid crystal bulk layer and the surface-director alignment layer exhibit dielectric anisotropies ($\Delta\epsilon$) of same sign.

4. A liquid crystal device according to claim 1, wherein the surface-director alignment layer comprises ~~regions~~ exhibiting dielectric anisotropies ($\Delta\epsilon$) of opposite signs.

5. A liquid crystal device according to claim 2 further comprising at least one confining substrate, and wherein an orthogonal projection of said surface director on said substrate, termed projected surface director, presents said preferred orientation in a geometrical plane in parallel with said substrate, termed preferred planar orientation, and said bulk layer is directly controllable by an applied electric field to perform an out-of-plane switching of said preferred planar orientation of the projected surface director.

~ natural parts.

6. A liquid crystal device according to claim 2 further comprising at least one confining substrate, and wherein an orthogonal projection of said surface director on a geometrical plane perpendicular to said substrate, termed projected surface director, presents said preferred orientation, termed preferred vertical orientation, and said bulk layer is directly controllable by an applied electric field to perform an out-of-plane switching of said preferred vertical orientation of the projected surface director.

7. A liquid crystal device according to claim 5 or claim 6, wherein the electric field is applied normally to said at least one confining substrate.

8. A liquid crystal device according to claim 3 and 4 further comprising at least one confining substrate, and wherein an orthogonal projection of said surface director on said substrate, termed projected surface director, presents said preferred orientation in a geometrical plane in parallel with said substrate, termed preferred planar orientation, and said surface-director alignment layer and said bulk layer are directly controllable by an applied electric field to perform an in-plane switching in the surface-director alignment layer and an in-plane switching of said preferred planar orientation of the projected surface director.

9. A liquid crystal device according to claim 8, wherein the electric field is applied in parallel with said at least one confining substrate.

10. A liquid crystal device according to any one of claims 1-9, wherein the liquid crystal bulk layer comprises a nematic liquid crystal.

11. A method for manufacturing a liquid crystal device comprising the steps of:

providing a surface-director alignment layer on an inner surface of at least one substrate, and

5 sandwiching a liquid crystal bulk layer between two substrates, said liquid crystal bulk layer presenting a surface director at a bulk surface thereof and being directly controllable by an electric field via dielectric coupling, and said surface-director alignment layer being
10 arranged to interact with the bulk layer at said bulk surface for obtaining a preferred orientation of the surface director of the bulk layer,

c h a r a c t e r i s e d in said surface alignment layer being directly controllable by an electric field
15 via dielectric coupling.

12. A method of controlling a liquid crystal bulk layer comprising the step of aligning a liquid crystal bulk layer presenting a surface director at a bulk surface thereof by use of a surface-director alignment layer
20 arranged to interact with the bulk layer at said bulk surface for obtaining a preferred orientation of the surface director of the bulk layer c h a r a c t e r i s e d in that the liquid crystal bulk layer and the surface-director alignment layer each are directly controllable
25 by an electric field via dielectric coupling.

Abstract

The invention relates to a liquid crystal device including a liquid crystal bulk layer and a surface-director alignment layer each being directly controllable
5 by an electric field via dielectric coupling, and thus resulting in a decreased total time period (rise and decay times) needed to switch and relax the liquid crystal bulk molecules in response to an applied external field.

The invention also relates to a method for manufacturing a liquid crystal device and a method of controlling a liquid crystal bulk layer.
10

15

20 Figure elected for publication: Fig 3